ENGINEERING EDUCATION

Bulletin of the

Society for the Promotion of Engineering Education

Published under the supervision of the Publication Committee:
Chas. F. Scott, Mortimer E. Cooley, F. L. Bishop, *Editor*.

The following, Chairmen of committees, are by action of the Council Co-operating editors.

JOHN AIREY,	W. S. FRANKLIN,	R. S. KIRBY,
R. M. BIRD,	E. R. HEDRICK,	W. T. MAGRUDER,
A. H. BLANCHARD,	C. S. HOWE,	J. R. NELSON,
H. E. DYCHE,	H. J. HUGHES,	L. L. THURSTONE,
J. T. FAIG,	D. C. JACKSON,	P. F. WALKER,
O. J. FERGUSON,	D. S. KIMBALL,	W. E. WICKENDEN.

VOL. XIII LANCASTER, PA., JANUARY, 1923 NO. 5

TABLE OF CONTENTS.

Editorial. F. G. Higbee. 246
Attendance at Engineering Schools. F. L. Bishop. 249
The English Department. 251
Comment in Reply. C. F. Scott. 252
The Education of the Intuitions. Arthur E. Morgan. 254
Intelligence tests for Engineering Students. L. L. Thurstone. 263

EDITORIAL.

THE FUTURE OF ENGINEERING EDUCATION.

What the engineer of tomorrow will be is very largely in the hands of the engineering educators of to-day. The character and standing of the engineering profession of the future will be determined by the policies adopted by technical schools within the next few years. It is, indeed, quite possible that neither the great body of engineers now practicing, nor many of those now engaged in the training of Young America, are aware of this critical condition, yet to those who are intently watching the development of Engineering Education it seems evident that a turn in the road has been reached. Sooner or later in the very immediate future it must be decided by those who control the educational policies of our engineering schools whether Engineering Education will continue along in the established direction, or whether it will leave the old way to follow a new course, as yet uncharted, which many of the pioneer educators of today believe will lead the profession to wider and richer opportunities.

Engineering education in the United States lacks but a year of being a century old; as one looks back over this one hundred years of progress and development, amazement grows as one discovers that for the first quarter of this century only two schools existed where engineers could be trained and that for more than half of this century only four schools were established. So it may be stated that engineering education, as it is to-day, is in reality, a development which has come about within the last fifty years. And only within the last thirty years, let it be remembered, has there been any organized effort to study and promote engineering education.

Never, during all this period, has any education specifically designed to train teachers of engineering subjects been offered. Never has there been any adequate inducement held out to

engineers to help in the perpetuation of their profession. And yet volunteers have been found who have not only kept alight the torch of learning but who also have added, immeasurably, to the store from which future engineering learning must draw its vitality. These pioneers have done this, moreover, under conditions which might well cause the teacher of to-day to falter and lose courage. During this period of development engineering science ran a wild race to hold even with the industrial and commercial demands of the era. Teachers of engineering have run, and won against, handicaps which were heavy: Text-books were obsolete before they were printed: laboratory equipment represented only the best practices of the year before; schedules were so stuffed with teaching hours that personal advancement could be made only by tremendous sacrifices. In the light of such conditions one may fairly assert that one of the great engineering achievements of to-day is engineering education.

During the last decade, for the first time in the whole history of engineering education, those now engaged in that work have had time to take an inventory. And what is being found?

Out of the welter of pertinent and impertinent discussion and criticism one large fact stands forth agreed upon both by those who train engineers and by those with whom the product of this training comes in contact: Engineering education has failed to give the breadth of training needed by the engineer of to-day and demanded of the engineer of tomorrow. His technical equipment is quite generally regarded as adequate but the background needed to make this technically trained engineer most useful to society is lacking.

In engineering service there is a marked division; there are those who plan and direct, and there are others who carry out these plans. Engineering schools must provide a training for both to be sure, but engineering educators have learned that they have been devoting themselves too much to the development of the latter type. Already there exists a demand for the engineer who possesses all of the technical training needed to carry out undertakings already planned and who

has the ability not only to plan such undertakings but also to foresee the need for them and who, foreseeing this need, can lead other men to share his vision.

To meet this demand is, in a word, the problem of engineering education. How promptly the engineering schools of this country attack this problem, and how successful they are in solving it, will very largely determine the future of the engineering profession. Is it not worth while for the Society for the Promotion of Engineering Education to concentrate its efforts and activities upon the solution of this problem? Is anything less vitally deserving of the attention of the Society until this problem is solved?

It is indeed fortunate for the engineering profession and for engineering education that at this critical moment there exists a society organized for the solution of just such problems and has at its head an officer who so clearly understands it and who has so definitely pointed out a method of attack. He and his efforts are deserving of the loyal coöperation both of the engineering profession and the engineering teachers, for under his leadership the engineering profession of today has a great opportunity.

F. G. HIGBEE,
Vice-President of the Society.

ATTENDANCE AT ENGINEERING SHOOLS.

BY F. L. BISHOP.

The United States Bureau of Education has obtained the following figures for attendance at engineering schools for the current year. A few of the smaller engineering schools have not reported.

The conclusions derived from this record are by the author.

The attendance for 1921–22:	
Freshmen and sophomores	32,178
Juniors	11,446
Seniors	8,520
The corresponding enrollment for 1922–23:	
Freshmen and sophomores	29,952
Juniors	10,383
Seniors	9,571
Total for 1921–22	52,144
Total for 1922–23	49,906
A decrease of attendance at engineering schools for the current year	2,238

From the 32,178 freshmen and sophomores enrolled in 1921–22 there appeared 10,383 juniors during the current year, or 32 per cent. We may fairly assume that the same ratio will hold for next year which means that there would be a total of 9,585 juniors for 1923–24.

From the 11,446 juniors of last year, we have 9,571 seniors during the current year, or 84 per cent. Again assuming that this represents a normal decrease from juniors to seniors, there would be 8,727 seniors in next year's class. It is to be noted from the above figures that the present Senior class has reached the maximum and that there will be a decrease of over 800 in next year's senior class.

The freshmen and sophomore classes will probably continue

at approximately the same rate of decrease for next year, although various factors would indicate that the decrease will be faster. Assuming the same rate of decrease there would be only 93 per cent. of the freshmen and sophomores in 1923–24 as are enrolled in the current year, or a total of 27,855 freshmen and sophomores for 1923–24.

The total enrollment in engineering schools will be approximately 46,167 for 1923–24, a decrease of about 3,700 over the current year and of about 6,000 over last year.

The conclusions are that the engineering schools have reached their maximum attendance for the present. This attendance is probably limited by the facilities of the schools.

THE ENGLISH DEPARTMENT.

AN OPEN LETTER

TO THE CHAIRMAN OF THE BOARD OF INVESTIGATION AND COÖRDINATION.

My dear Professor Scott:

The creation by the Society for the Promotion of Engineering Education of a Board of Investigation and Coördination has certainly quickened the hope of the English Committee for an adequate and comprehensive study of the place which training in English should hold in the preparation of engineering students for their professional work. This hope that some day by some means our place in the general scheme of engineering education might be more exactly defined has descended to the present committee by a very honorable inheritance, from such enthusiastic and discriminating students of our common educational problems as Samuel Chandler Earle, of Tufts College, Frank Aydelotte, of Swarthmore College, and C. W. Park, of the University of Cincinnati, former chairmen of the committee. A considerable amount of research was done by previous committees under the direction of these men, and a considerable volume of data accumulated so that at least a fair appraisal has been possible of the status of English teaching in our engineering colleges, and, chaotic though it may seem as to methods of organization and administration, it has come to be recognized as having common objectives that are fairly well defined. The present committee, feeling that the time had come for more vital personal contact between teachers of English than could be gained through correspondence, has gone a step further and inaugurated an annual conference of those interested in the study of this particular problem in engineering education. The Conference at Urbana even succeeded in agreeing upon a fairly concrete statement of the objectives, the methods of approach

and of procedure in the teaching of English to engineering students. Viewed thus in retrospect, the actual contribution of the English Committee over a period of years to the development of engineering education is not without significance.

But it should be recognized—and the committee itself is most alive to this limitation upon its work—that the studies so far made of the place of English training in the engineering curriculum, and of the most effective means of coördinating such training with that in technical subjects, have all been made by the English teachers themselves, and, however conscientiously they have tried to look at the problem from the viewpoint of the future service of their students to the engineering profession and to society, their conclusions may need checking at least. It is, therefore, like an answer to a long prayer, that at last an official board of so influential a society as the Society for the Promotion of Engineering Education is preparing to investigate in a large and adequate manner the problems of engineering education. As a committee of that society we are confident that our particular problem, though only one of many demanding study, will receive sympathetic and intelligent consideration. We bespeak such consideration, and urge your board not to overlook our needs, as you plan for your investigation.

I am sure, Mr. Chairman, that I am expressing not only my own personal feeling, but the unanimous sentiment of my committee, when I assure you that the English Committee of the Society for the Promotion of Engineering Education is ready to coöperate in every way with the newly constituted board.

Very respectfully yours,

J. Raleigh Nelson,

Chairman of the English Committee.

COMMENT IN REPLY.

The foregoing letter was presented to the Board. The teaching of English is an important matter and the Board was gratified by the request for its coöperation.

COMMENT IN REPLY.

I was personally impressed with the rather startling assertion that the training of English has not met with constructive interest on the part of engineering teachers. I had always thought that this was more emphasized than any other single factor entering engineering education.

English teachers are to be highly commended for the good work they have done and I am sure that this Society and its new Board will endeavor to bring the engineering teachers themselves into hearty and effective coöperation with the teachers of English. Presumably the details of organization and methods will lie largely with the Committee on English. But I am sure I speak correctly for the Board in saying that such an important subject will receive early consideration.

C. F. Scott,

Chairman, Board of Investigation and Coördination.

THE EDUCATION OF THE INTUITIONS.

BY ARTHUR E. MORGAN,

President, Antioch College, Yellow Springs, Ohio.

Under the term "intuitions" I include all those attitudes, ideas, judgments, appraisals, conclusions and opinions which seem to spring spontaneously into being, and which do not come as the conclusion of conscious reasoning or analysis. These range all the way from motor intuitions, such as those by which we keep our balance when we walk, to moral intuitions which assert themselves when we undertake to determine far-reaching issues of conduct. With the lower animals the intuitions seem to play an almost exclusive part in the guidance of behavior; in man they share this guidance with analysis and other forms of reason.

The profession of engineering originated, to speak a bit summarily, when men began in material design and construction to supplant intuition by analysis. In pre-engineering days the elements of mechanical construction, especially whenever they went beyond the arbitrary rules and judgments determined by trial and error, were generally arrived at by a sense of fitness—by intuition.

In Schiller's poem, "The Song of the Bell" we have a picture of the old bell founder's intuition and traditional craftsmanship:

> Wie sich schon die Pfeifen bräunen!
> Dieses Stäbchen tauch' ich ein,
> Sehn wir's überglast erscheinen,
> Wird's zum Gusse zeitig sein.
> Jetzt, Gesellen, frisch!
> Prüft mir das Gemisch,
> Ob das Spröde mit dem Weichen
> Sich vereint zum guten Zeichen.

The modern metallurgist, with his precise methods of analysis,

of synthesis, and of tests, can make far better bells, far better swords, and far better metal products of every kind, than any medieval craftsman with the most highly developed intuitions.

The old-time millwright or architect designed his trusses, beams and arches by a sense of fitness. When this quality rose to the magnitude of genius, as in Michelangelo, great masterpieces of construction resulted; but I suspect that even in the case of St. Peter's, an accurate engineering analysis would disclose much uneconomical use of materials. In its structural features that building probably could be devised to-day by a comparatively commonplace engineer, using scientific analysis and design in the place of intuition.

Our modern industrial world, with its unprecedented revolution in the conditions of living, is largely the result of the replacement of the indefinite and inexact processes of intuition by the precise and dependable methods of analysis. Little by little the engineer is demanding an increasing place in the affairs of life. Scarcely a year passes but that some new field is snatched from intuition and added to his domain; and this fact is one of our most hopeful assurances for the permanence of civilization.

Our technical schools owe their rise and their dominating position to their appreciation of the value of analysis—of careful observation, precise measurement, and calculated design. Our liberal colleges up to recent years were dedicated to the education of the intuitions; to bringing into the student's life a great variety of wisely selected disciplines, outlooks, estimates, appraisals, and appreciations; nearly all qualitative, and, except in mathematics and physics, very few quantitative; in the hope that out of this general process he would come to develop intuitions that are true guides and effective controls. During the last fifty years the introduction of science courses into our liberal colleges has to some degree added the element of quantitative thinking, but these distinctions in the main still hold. A thousand years of liberal education, though it laid the foundations of disciplined thinking, failed to bring about a hundredth part of the control of our physical universe that

has been accomplished in a hundred and fifty years of science and engineering.

Now, having paid full respect to the part played by scientific analysis and design in modern life, I can assert with less fear of misunderstanding that *the chief defect in technical education to-day is our failure to educate the intuitions.* The tremendous power conferred upon men by the processes of analysis and orderly design has absorbed our attention. We ignore the fact that these processes are dependable guides for but a very small part of our activities. At best they are but tools or servants by which intuitive purposes are accomplished.

All men and women, including technicians and engineers, live in the main by intuition, and to a very minor extent by the scientific processes of mathematical analysis, precise measurement, and formal design. Our technical schools have given their students the impression, through the courses of studies offered and required to be taken, that the professional life of the technical man is largely a succession of analytical processes. As a matter of fact, in the professional work of most engineers who have gone beyond the stage of routine computers, decisions which must be arrived at by intuition both outnumber and outweigh those which can be reached by a purely technical approach. Even for the technical engineer, relations with people are more fundamental than relations with things, even when those things are the all-important *materials of construction.*

Because our technical schools largely limit themselves to education in technical principles and processes, and to such a large degree omit any broad education of the intuitions, the typical product of these schools finds his preparation at graduation to be embarrassingly incomplete. His status would be far more unsatisfactory but for the fact that, having had men of fine personal standards for teachers, within certain limits his intuitions have been thoroughly trained (there is perhaps no calling in which standards of professional integrity are higher) and because home and college environment and many

other associations tend to correct what otherwise would be an almost fatal defect in his college curriculum.

Intuitions are not vagrants, arriving from nowhere and without cause or parentage. Rather they are normal and natural offspring, to some extent of heredity, but in very great measure of education and environment. The character of these intuitional ideas, judgments and appraisals, which in the main will determine the course of the student's life in after years, to a very great degree is being formed, or left unformed, during his college life. They, too, are susceptible of education. To the extent that his attention at college is confined to a consideration of technical principles and processes, his intuitions, outside of these phases which technical training specifically develops, will remain narrow, instinctive, primitive and crude, and made up of comparatively few factors.

Technical skill does not directly originate purposes. It only serves to discipline and to bring to fruition purposes which originate in the intuitions. The worst possible state of society would be that in which the greatest technical skill would serve purposes originated by the crudest and most unenlightened intuitions.

At Antioch College we are endeavoring to develop a curriculum in which the various elements of education will be given time and place in the proportions which will tend most to insure success, both in a vocational and in a personal and social sense, and so to distribute the time and effort of the student that his total equipment for life will be most effective. For his technical preparation we provide first, general training in the methods and spirit of science, dwelling upon accuracy of observation, carefulness of records, precision in measurements, the elimination of the personal equation, the control of variables, and other factors that determine the value of research and investigation; second, training in the fundamental sciences underlying his calling, and third, the technical principles relating to their application. However, it is not the object of this article to discuss these methods of technical education.

For the education of the general intuitions we have two widely different processes, both of which we consider to be necessary to symmetrical development. The first of these consists of including in the required curriculum of all technical students, courses in the fundamentals of so-called cultural subjects. These include literature, history, economics, sociology, philosophy, psychology, biology, geology, physics, and chemistry. The primary object of these courses is so to develop the student's mind and spirit that his intuitions will furnish the best possible motives and the soundest possible judgments.

For example, acquaintance with great literature enormmously extends the range of the student's concepts. He finds men moved by powerful emotions which he had experienced but faintly if at all in himself, he discovers new motives, new outlooks, new discriminations, new appraisals of values. All these experiences of other men in some measure become part of himself, enter into the formation of his intuitions, and help to determine their character. The same is true of the effect of certain other so-called cultural studies.

The intuitions which are enlarged and refined by liberal education affect both his professional work and his personal and social life. One engineer finds his intuitions satisfied when he has built a bridge that will stand up under maximum stress; while another whose intuitions reflect a wider training is not satisfied unless the bridge also fits into its environment as a thing of beauty; one finds his intuitions satisfied if he does his job within his estimate; another demands in addition that the workmen employed on the job shall have decent and sanitary working and living conditions. At every step in his professional life, the character and quality of the engineer's work is affected by those spontaneous ideas and judgments which we define as intuitions, and these in turn are profoundly modified by his past environment and training.

But the engineer is not only a producer, he is a human being with a personal life to live, and with family, social,

and civic relations. Whether it be in choosing a wife, in selecting a home, in making friends, in political party alignments, or in any other of his varied activities, his intuitions generally control, and they have been profoundly modified by his previous educational environment. That is true liberal education which gives one discriminating awareness of the greatest possible range of values, and sound judgment as to their relative importance; and these qualities the engineer needs as surely as does anyone else. The essentials of liberal education need frequently to be redetermined to meet the needs of ever-changing conditions of life. At Antioch we have departed far from liberal college traditions in our estimates of the comparative values of "cultural" subjects.

So much for so-called liberal education. There is another and very different process by which the intuitions must be educated if the engineer is to reach his fullest development. In the handling of purely professional problems he finds that the factors considered in the books are but a part—commonly a small part—of those which actually affect the consummation of his designs; and the foreseeing of these indefinite factors, and commonly their proper appraisal, is a matter of intuition. The difference between the reliable man of experience and the unreliable theorist is the difference between the possession or lack of this kind of intuition.

The conventional ideal of professional training would have the student's development run as follows: first there would be a liberal college course, during which the student applies himself to the usual liberal college curriculum, and grows culturally; then comes a technical schooling, during which he masters the theory of his profession, and lastly he enters practical life, and finds occasion for the development of judgment. Now as a matter of fact, students do not develop in this way, first culturally, then technically, and then in practical judgment. They are growing all over all the time. At no time are they keener to observe and appraise practical considerations than in their early years, and only as they approach maturity and have a background of experience can

some of the larger inferences of their cultural studies reach them. If we should decide to exercise the student's arms for a year, until they had developed to full size, and then to exercise his legs, we should be scarcely more unreasonable than in our policy of developing his mental faculties tandem fashion—one after the other.

The greatest economy of the student's time will result if we let his mind develop symmetrically, as we do his body. For that reason, at Antioch we provide for the education of those intuitions which receive their development in the practical contacts of life. The part-time work of our students is not primarily to train them in callings or to contribute to self-support, though these are by no means negligible gains; but to lay the basis for dependable intuitions.

Do my available resources of energy, will, and knowledge justify me in attempting the project in view? Unless my intuitions are advised by past experience, they may play me false. This man who offers me a business association—will he play fair? Only intuitions trained by many contacts will tell me the truth. In this project I am about to undertake, what are the relative magnitudes of the factors I can see and appraise, and those other uncertainties which cannot be foreseen, but which are sure to arise? The engineer commonly makes a poor contractor because his intuitions are not trained to make this appraisal. He has been educated to consider only factors that present themselves for analysis.

We should not postpone the engineer's first effort at figuring stresses until the occasion when he is solely responsible for designing a great bridge. Yet we postpone opportunity for him to develop these practical intuitions until his after-college days, when he is playing for great stakes, commonly for the success or failure of his life's effort. The aim of part-time work at Antioch is to furnish occasion for the education of the intuitions at a time when the results of inevitable mistakes will not be fatal, when frequent changes in work and environment can be made to enlarge experience greatly, when experiences can be interpreted by mature and

experienced advisers, and in an atmosphere where the study and analysis of practical experiences make them yield their full contribution to the education of the intuitions. These educational results of part-time work had been amply demonstrated by Dean Schneider of Cincinnati, before they were incorporated in the Antioch plan.

The following is a brief outline of the Antioch program. While we make provision for full-time students, between eighty and ninety per cent. of those enrolled spend half time at college and half time at practical work in appropriate callings, in alternate periods of five weeks. Antioch College is located at Yellow Springs, Ohio, within easy reach of Springfield, Dayton, Columbus, and other commercial, professional, and industrial centers, so that opportunities for practical work are abundant. The college is coeducational, and girls are given opportunities which accord with their interests.

Of the school periods, about half the time is taken up with so-called cultural studies and, for most of the students, the remainder is occupied with specificially technical training. Some of the required cultural subjects also have value in technical training, as physics, chemistry, geology, and biology, for engineers. The specific vocational aim of Antioch is to train men and women for administration and proprietorship (including home administration and institutional management for girls who do not prefer commercial, professional or industrial life). Our aim throughout is to develop generalists rather than specialists; Antioch's "specialty" being the training of its students for the function of coördination and management, in commerce, industry and the professions.

In training mechanical or civil engineers, for example, the purely technical courses are limited to such fundamentals as physics, mechanics, and dynamics; with aid for the student who wishes to pursue his own way in more advanced work in any technical subject through "autonomous" courses. A very considerable part of his time is given to courses in

the technic of management, such as cost accounting and analysis, employment relations, publicity, traffic, purchasing, production engineering, and industrial research. If he is to be a civil engineer, his relation to his calling will be primarily that of administrator, superintendent, proprietor or manager, rather than that of technical specialist. Similar preparation is given for administration in other professions, and in industry and commerce. The course requires six years of forty weeks each for the average student. Particularly able students can reduce this time by a year.

In its choice of training for administration and proprietorship as its special field, Antioch has endeavored to avoid so far as possible competition with our great technical schools where students aiming to become highly specialized technicians have facilities and an atmosphere suited to the purpose; it has endeavored to prepare its students for fields of effort where symmetrical development, including the education of the intuitions, is most essential to success.

In its special field of training a small, selected group of students for administration and proprietorship, Antioch is typical only in that it suggests the adoption of definite and limited vocational purposes as the way out for our small colleges. In its determination to build its special training upon the broad foundation of symmetrical development, including practical experience with the affairs of life, we hope we may develop timely and valuable suggestions for the general field of engineering education.

INTELLIGENCE TESTS FOR ENGINEERING STUDENTS.

L. L. THURSTONE, *Chairman, Committee No. 22.*

Carnegie Institute of Technology, Pittsburgh, Pa.

Purpose of the Investigation.

In the fall of 1919, Committee 22 on Intelligence Tests of the Society for the Promotion of Engineering Education induced a number of engineering schools to participate in a coöperative study of the predictive value of various kinds of examinations. Interest at that time was directed toward intelligence tests, trade tests, objectively scored examinations, and other recent developments in examination technique. The committee was asked to investigate the possible practical usefulness of these new types of examinations for engineering schools. The results of such an investigation might reasonably be expected to bear on the provision of entrance requirements and entrance examinations for engineering colleges.

The committee consists of the following members:

W. T. Magruder, Ohio State University,
Anson Marston, Iowa State College,
D. C. Jackson, Massachusetts Institute of Technology,
C. R. Dooley, Standard Oil Company,
L. L. Thurstone, Chairman, Carnegie Institute of Technology.

One of the important facts that turn our attention to the methods of selecting and admitting students to the engineering schools is the great number of failures and withdrawals from college. Many of the students who leave college do so for good reasons such as illness or financial difficulties but many leave because of inability to carry the courses. It is difficult to estimate the harm that is done by

eliminating thousands of college students because of scholastic failure. The discouragement of a scholastic failure is likely to influence the student's confidence and his personality in subsequent undertakings. It may be argued that a student who fails sometime during his first year of college work has nevertheless gained something from his stay in college, but the value of his studies terminated by expulsion is doubtful. It is obviously of general interest so to improve our methods of student selection that we may reduce to a minimum the discouragement of failure in college. If the abilities of the applicants can be determined before admission we shall be able to advise the student regarding his contemplated college course to his own advantage.

In Fig. 1 is shown graphically the rate at which the students withdrew from college. We made a list of all the students who entered the engineering college at Carnegie Institute of Technology in the fall of 1919. The total number of students admitted in this class was 490. This number is called 100 per cent. The subsequent ordinates in Figure 1 represent the percentage of the original size of the class that remained after any given number of months. The college was at that time organized on the quarter plan and consequently the greatest drops occur after three months, nine months, and eighteen months, representing the end of the first quarter, the first year, and the second year respectively. At the end of the second year there remained only 32 per cent. of those who entered as freshmen. In two years the size of the class was reduced to one third of its original number. In considering these facts it should be borne in mind that the entering classes in 1919 were unusually large and the colleges were unable to take care of the suddenly increased number of applicants. The mortality of entering classes in other years is not quite so pronounced. It would seem possible to determine beforehand the probable fate of a considerable number of these students.

The purpose of this investigation is to analyze the relative value of various facts that are known before admission of

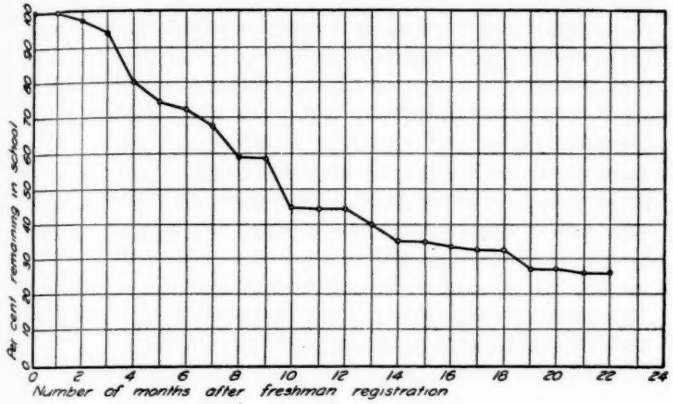

Per cent remaining in school
0 10 20 30 40 50 60 70 80 90 100
0 2 4 6 8 10 12 14 16 18 20 22 24
Number of months after freshman registration

FIG. 1.

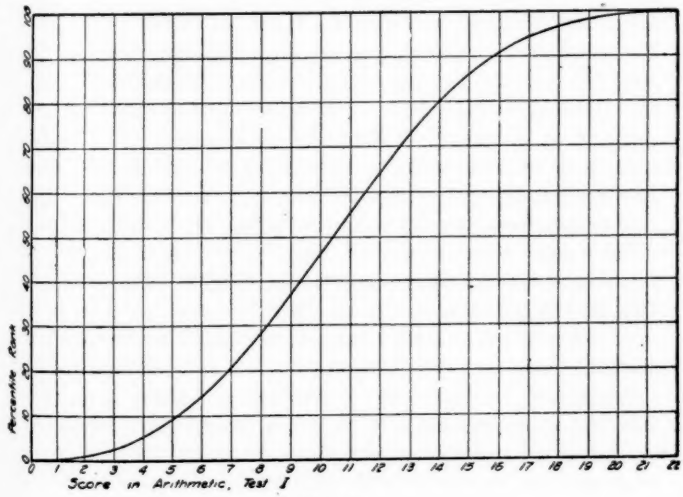

Percentile Rank
0 10 20 30 40 50 60 70 80 90 100
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22
Score in Arithmetic, Test I

FIG. 2.

students. The relative value of these facts is determined with special reference to subsequent scholastic performance. By studying various facts about the applicant and the relation between these facts and his subsequent record it will be possible to select those facts which are diagnostic of future success or failure and to discard from our requirements those facts which do not predict what the student will do. The problem can be solved by the application of objective scientific method although the final solution may be slow in com-

The Admissions Problem.

Before analyzing the statistical findings for the special examinations prepared by Committee 22 it will be advisable to consider the possible relationship of these examinations to the admissions problem.

Applicants for admission to the engineering colleges are accepted usually by one of three methods, namely, high school certification, entrance examinations, and the College Entrance Board examinations or their equivalent such as the New York State Regents examinations. It should be possible to analyze the relative predictive value of these various methods of admitting students by determining the correlation between the examination grades or the high school scholarship in specified subjects on the one hand and the college scholarship records on the other. Such studies will enable us to adopt the methods which work best in the majority of cases. This study is intended to give some information on this problem and it should also serve as an example of the statistical methods that will be found serviceable for such studies.

Attention is called to the possibility of looking at college entrance examinations as a part of a program of vocational guidance. The examinations serve, no doubt, the purposes of vocational or educational guidance, but the attitude of the examiners who conduct college entrance examinations is not always that of educational advice. The attitude is perhaps too often one of presenting certain mental hurdles for

the applicant to jump, certain difficulties in his road. If the applicant succeeds he is accepted but if he fails he is merely rejected. The attitude of educational advice would be slightly different although the form and procedure might remain almost the same. It is believed that we shall make better progress in selecting students if we adopt the scientific attitude of vocational guidance in preparing entrance examinations. The examinations should not be looked upon as fixed entities which retain their value by the authority back of them. The examinations should be looked upon as methods of educational guidance which are subject to continual revision in form and content in the light of statistical studies. An examiner should not take offense if the particular examination that he has prepared does not prove to be diagnostic of collegiate success. When an examination is found to be of low predictive value we should be willing to revise our methods of conducting the examination, or the form and content of the examination, until we shall have arrived at educational guidance methods with a minimum of diagnostic error.

What is Engineering?

If we consider the problem of educational advice to prospective engineering students we come upon a fundamental difficulty with regard to the nature of engineering. If we conduct examinations in order to determine the applicant's fitness for engineering it behooves us to know what engineering is. If we define engineering broadly as the utilization of the forces of nature for good purposes, the definition becomes so vague that engineering loses its identity as a profession. As long as the subject matter of engineering is frankly acknowledged to center in the applications of physics to static structures and machines, the profession has an identity. The tendency is, however, to extend the scope of engineering to include such widely different interests as machine design, chemistry, salesmanship, advertising, finance, management, and how to get along with people. As a conse-

quence we have chemical engineering, commercial engineering, human engineering, and many other varieties that deviate so much from the applications of physics to static and moving structures that the identity of the profession is almost entirely lost.

It is absolutely essential for the educational and vocational counsellor to take these facts into consideration. If a boy fails in machine design and in mathematics he may still become an engineer. It is only necessary for him to declare that he is a commercial engineer, a human engineer, that he can "engineer" something that is non-technical. Suppose that a boy is considering engineering as his life work and that he has never had any interest in mathematics, physics, mechanics, machines, electrical devices, and tools. Should we advise him to stay out of engineering? That is a very real question. The boy might succeed in engineering anyway by choosing a course in administrative engineering. He does not need to worry about machine design and mathematics because he is going to train himself to be a leader, the chief who merely dictates to the ordinary engineer what is to be done. He wants to be the kind of engineer who is a leader in industry, not the ordinary kind of engineer who invents and designs and who solves problems that are scientifically intricate. He also has the option of becoming a sales engineer with emphasis on sales. What can the vocational counsellor do with such wonderful possibilities?

From the standpoint of vocational counselling, it is useful to make a comparison between engineering and other professions such as medicine and law. The vocational counsellor notices first the fact that medicine and law are two rather stable professions so that one can be fairly certain what it is that one is advising a student about at least as regards the professional courses in medicine and law. The counsellor is, however, uncertain what engineering is if we allow that engineering includes finance, selling, management, advertising, chemistry, sanitation, accounting, and almost everything else. The counsellor must of course recognize that

every profession has such a wide variety of activities that almost any temperament and interest can find a place in it. This is true of medicine and law just as well as of engineering. But there is one fundamental difference for the counsellor to consider. The professional course by which a student may enter the profession of medicine or that of law is fairly stable. The professional course by which a student may enter the engineering profession is very flexible. If the student finds that he has no talent in machine design, mechanics, and mathematics, he may still become an engineer. He may still be able to complete a professional course in engineering by selecting a different kind of engineering. Hence it becomes precarious to advise any student not to enter the engineering profession. It would almost seem as if anyone with collegiate intelligence can enter engineering, and the problem would reduce itself to the selection of the right kind of engineering for anyone who goes to college. If the expansion of the subject matter of engineering continues the engineering profession will lose its identity.

The fact that the engineering profession is losing its identity may constitute an educational advantage rather than a disadvantage, but we should at least be aware of it. The fact that engineering courses are flexible makes it possible for a college student to find himself in one of the many lines of work which are loosely organized under the general heading, engineering. This constitutes an advantage for the student and it may constitute an advantage for the educational counsellor.

There are several factors that are responsible for the heterogeneous character of the engineering profession. One outstanding fact is that the entry into the profession is not marked by the attainment of a uniform college degree. If a man proposes to enter the medical profession he must set the M.D. degree as his first objective. A man is either a physician or he is not a physician. He has the M.D. degree or he has it not. There is no middle ground. The conditions are closely similar in the legal profession. A man has the uni-

form LL.B. degree or he does not have it. The counsellor has therefore a fairly definite course to talk about when advising with students about the medical and legal professions. There is no such uniform course of study by which to enter the engineering profession. We have several dozen engineering courses from which to select and as many different engineering degrees by which to enter the profession.

The fundamental reason for this is probably to be found in the fact of state certification. The medical and legal professions require state certification for practice and that has tended to keep fairly uniform the courses by which students prepare to enter those professions. Since the engineering profession does not depend upon state certification, the schools have felt free to vary indefinitely the engineering courses and the engineering degrees. While this constitutes an advantage to the student who is trying to find himself it has also resulted in the disappearance of engineering as a distinct profession. We can not say that a man is either an engineer or he is not an engineer. Anyone can call himself an engineer, and there is room for legitimate difference of opinion as to whether any particular man is or is not an engineer. Two engineers do not necessarily have anything in common.

As a result of these circumstances there is a fundamental difference between specialization in the medical profession and specialization in the engineering profession. Specialization in medicine follows the attainment of the professional degree. One must first enter the medical profession by the uniform route of the M.D. degree before beginning to specialize. One can begin to specialize in engineering in the freshman year in college before entering the profession. Specialization in engineering is marked by the attainment of a specialty degree. The result is that the engineering profession does not have the corporate spirit nor the solidarity that is evident in the medical and legal professions.

Is Manual Skill Necessary for Success in Engineering?

Perhaps it sounds absurd to ask whether a mechanical en-

gineer should possess manual skill in order to be successful. The engineer does not rely on manual skill in the same sense as the tradesman relies on manual skill to earn his living. The typical work of an engineer is mental rather than manual. The engineering student is not expected to acquire manual skill in the shop courses of the curriculum but he is of course expected to learn enough about the possibilities and limitations of the machine tools and the shop operations so that he will not design things that can not be economically manufactured. There is, however, a difference of opinion among engineering teachers on this point. Some teachers insist that a man is really not an engineer unless he does possess the skill of a machinist or at least considerable aptitude for manual work. Others insist that the engineer can be successful without possessing aptitude for manual work.

For the purposes of vocational guidance it would be valuable to ascertain whether successful engineers are in general dexterous with their hands and with tools. It seems reasonable to assume that a boy whose interests are in the direction of engineering will during his youth acquire considerable practice in using tools and mechanical appliances. Such aptitude could perhaps be interpreted as diagnostic of engineering talent. On the other hand it is conceivable that a boy may succeed in engineering largely by mental attainments even though he possess little aptitude with his hands because of the fact that engineering work is primarily mental. This question could be answered better by a simple survey or questionnaire than by discussion.

Purposes of Examinations.

A state university which admits all the high school graduates of the state who apply for admission is not in a position to require examinations for the purpose of selecting its students. It accepts all the high school graduates who apply for admission. In such a situation vocational guidance examinations can only be used for advisory purposes. If the examinations are given uniformly to all the students after

admission it is possible to infer with some degree of reliability what may be expected of them. A student who is weak in the preliminary examinations may be advised to carry fewer studies than the student who attains high marks. Higher scholarship attainment should be expected of the student who enters with a high examination grade than one should expect of the student who reveals by the preliminary examinations that he is entering college with a handicap in preparation or in ability. In some instances the separation of the freshmen into sections in accordance with their ability and preparation can be effected largely on the basis of the preliminary examinations.

This investigation was done jointly by a large number of engineering colleges to ascertain the relative practical value of examinations of the objective sort in comparison with high school marks as determiners of college admission and prognosis.

II.

Examination Technique.

Examinations for Endowment and for Educational Achievement.

The examinations to which we are accustomed are usually aimed to measure the extent to which a student has profited from formal instruction in a specified course of study. There has recently come to the attention of educators another sort of examination which has for its primary purpose the measurement of native endowment. It is probably impossible to separate the two objectives entirely. An examination of the usual educational variety measures not only the amount of information or skill that the student has attained but also indirectly his mentality which must have been used in reaching the indicated educational achievement. An examination in which we attempt to measure native endowment depends at least on the skill of reading, writing, or speaking, and to this extent it is also dependent on educational attainments.

The distinction between the two forms of examination is more one of emphasis than of kind. Students who come to a university vary greatly in the educational opportunities and in the teaching skill to which they have been exposed, and it is the intention of those who favor the supplementary examinations for native endowment to balance as far as possible these unequal factors in order to rate the incoming student more fairly.

The examinations for native endowment divide themselves again into two large classes, those examinations which are intended to measure general intelligence or mental alertness, and those which are devised to measure some special ability. Examples of special abilities are ability in mathematics, poetry, manual skill, freehand drawing, music. A special ability is any trait which one may lack and still be considered bright and intelligent. Vocational guidance methods must take into account not only the general level of intelligence or mental alertness required by any particular occupation but these methods must also take into account the special abilities that are required for success in any given occupation.

Aptitude Tests.

The so-called aptitude tests are intended to measure the native endowment, the capacity to learn in any given field. If, for example, we devise a test for stenographers we should expect it to be a letter which the candidate takes in shorthand and afterwards transcribes. The test mark would be a measure of the ability of the stenographer to take dictation and to transcribe her stenographic notes. But if we devise an aptitude test for stenographers it could not possibly be of this nature because we should then be dealing with people who have not yet learned shorthand. Our purpose with the aptitude test would be to determine whether the candidate can readily learn stenography and typewriting. I meet not infrequently a misunderstanding as to what is meant by aptitude examinations. A boy's aptitude for

geometry can not be inferred from an examination in geometry itself unless he has had a course of instruction in the subject. It is possible, however, to determine with fair degree of reliability whether a boy will succeed well with a course in geometry. The aptitude test given for this purpose is not a test in geometry, which the boy has not yet studied, but a test involving fundamentally the same sort of thinking and the same sort of imagination on the level of the boy's previous general experience. It is for this reason that an aptitude test is not so obvious in character as an ordinary examination for measuring achievement.

Trade Tests.

The trade test is an achievement test and is more obvious as to its purpose. A trade test for carpenters is a test in which one asks the candidate questions about carpentry and in which the candidate performs specified tasks in carpentry. The result of the examination, if it is a good one, is a measure of the candidate's achievement and present ability in carpentry.

Time-limit Examinations.

An examination may be given for the primary purpose of determining whether or not the student can solve certain problems with secondary emphasis on the length of time that he requires to solve them. Most of the college examinations are of this sort. If we are interested to know how fast the student works we may give the examination in one of two ways. These two methods of measuring the speed element in examinations are known as the time-limit method and the amount-limit method respectively. The amount-limit method consists in giving all the students the same number of problems. We ask them all to finish all the problems and we note the length of time required by each student. The constant number of problems in the examination divided by the total time as measured for each student gives an index of his speed of work. The time-limit method consists in giving

more problems in the examination than can possibly be solved by the fastest student in the time allowed. We allow all the students the same amount of time for the examination. All students start at the same time and they all stop working at the same time. The amount that the student can do in the given time will be his index of speed of work.

These two methods are logically on a par as far as the measurement of speed of work is concerned. The two methods are, however, not equal in ease of administration. It is relatively difficult to record the total time for each student when a large number of students are taking the examination simultaneously. For this reason the time-limit method is usually preferred in group examinations. The examination paper contains more problems than can possibly be solved by the fastest student. This insures that all the students are kept busy for a constant length of time. The speed of work is determined by the amount of work done in constant time. When examinations are conducted on this basis it is necessary to warn the students that there are more problems than they can solve and that this arrangement is intentional. They are requested to solve as many as they can in the time allowed.

There is a general prejudice against time-limit examinations based on the assumption that one can not do one's best when forced to work against time. (The writer formerly held the same opinion although I had no experimental proof to support the opinion.) We gave a series of examinations both with and without the pressure of working against time, and found that in all the examinations the diagnostic value was considerably increased by giving the tests on the time-limit basis. It is true that our best work is not done to the time of a stop watch but it is also true that, other things being equal, the brightest minds can not only work better but also faster than the less gifted minds. Why should we then not avail ourselves of one of the fundamental differences between brightness and dullness, namely, the difference in the normal speed of mental work. It has been established with

considerable certainty that an examination is more diagnostic of the ability measured if we take into consideration the speed with which the student works.

As a general rule the time-limit examinations differ from the customary school examinations in another particular also. The time-limit examinations usually consist of quite a number of relatively simple problems rather than a small number of problems that are for the student relatively complex. It is reasonably certain from experimental work on examination procedure that the reliability of an examination is considerably enhanced if it consists of a large number of relatively smaller problems. An accidental right or wrong answer on any single problem does not so readily influence the student's relative standing in comparison with his classmates if the examination consists of a large number of problems that are given by the time-limit method. There is no reason why these methods of examination technique should be limited to the aptitude or intelligence examinations. The same methods may be applied to examinations in any subject.

The Criterion.

In devising any vocational guidance procedure or in constructing any test that is supposed to be diagnostic of a specified trait or achievement, it is highly essential that some criterion be adopted against which the diagnostic value of the test may be checked. If we are devising a test for mathematical ability which is to be given to strangers, it is essential that we adopt some criterion against which to check the test before pronouncing it to be a test of mathematical ability. The test would first be given to a group of people about whom we know something regarding their mathematical ability. The group should contain people who are superior in this trait and also people who are average and inferior in it. If the test agrees with what we already know about the mathematical ability of the group selected for initial study, then we are justified in saying that the test is diagnostic of mathematical ability and we are then ready to give the test

to strangers in order to measure their mathematical ability. The criterion is in this case our judgments of mathematical ability of people whose attainments are already known to us. Many mental examinations are prepared without any regard for the necessity of establishing the practical value of the test by checking it against an independent criterion. It is only after showing that the test agrees with the known abilities of the initial sample group of persons that we can say anything at all about the diagnostic value of a test. Of course if one type of test has established its diagnostic value we are justified in devising other similar examinations without again establishing the diagnostic value for each new edition of the examination.

Scholarship as Criterion.

When we are devising methods of selecting students we must have some criterion against which to check the various methods of selection and admission. If we want to ascertain whether high school scholarship or entrance examinations are most diagnostic of success we must define objectively what we mean by success. The natural criterion is scholarship. Those students who remain in college with good scholarship would be considered to be successful and those who fail in college scholarship would be considered unsuccessful. There has been much criticism against scholarship as a measure of success, of professional promise, of ability. It is undoubtedly true that scholarship is not an infallible index of future professional success but it is the only definite measure that we can use for our present purposes. As long as scholarship is the factor which determines whether or not the student is to be allowed to enter the profession in the regular way, we are justified in retaining college scholarship as our measure of success. If our curricula should be altered in some fundamental respect we should be justified in again determining the relative values of different methods of selecting our students. As long as we retain scholarship as the main criterion by which a student is admitted to the profes-

sion by the degree we are justified in using scholarship as the best available index of future professional success.

Objective Examination Methods.

The recently developed examination methods make liberal use of the so-called objective procedure. The fundamental idea underlying the objective examination method is to eliminate the personal equation as far as possible and to construct the examination questions in such a way that the candidate would have the same score no matter who marks the paper. This is a legitimate object to have in mind when constructing examinations. If the method is used by inexperienced examiners it is possible to reduce the examinations to a stereotyped form in which mere repetition of memorized facts is given more weight than the independent use of the candidate's intelligence in meeting new situations. This constitutes no necessary limitation of the objective examination method.

In order to make the examination such that different examiners may be certain to give the same mark to the candidate's paper several simple rules have been adopted for the construction of examination questions which may be summarized as follows.

Devise each question so that the answer to it is definite. Specify the units in which the answer is to be given. Specify if possible a definite space on the examination blank for the answer. Reword the questions if necessary so that double interpretations are avoided.

Mark the candidate's answer solely by the product, the answer to the question or problem. Do not allow any credit for indirect evidence of insight. If the student's calculations seem to indicate that he understands the problem and if he gives the wrong answer by any error whatever the answer is nevertheless wrong and credit is withdrawn. The mark depends solely on the correctness of the answer called for in a specified place. In practical work of any kind one is not excused for making mistakes even if one understands

the nature of the problem. One is judged in life by what one actually produces. Examinations can well be conducted on the same plan.

In order to measure mastery of the subject rather than the mere memory of isolated facts, phrase the questions so that some independent and more or less original thinking is necessary in order to solve the problem. The student who works conscientiously like a memorizing machine does not do well with examinations of this kind and it is proper that he should be handicapped and rated lower than the student who has some originality in the use of the information that he possesses.

The reliability or dependability of the examination mark is raised considerably by constructing the examination with a large number of relatively simple original problems instead of a few relatively complex problems. Any accidental error of the student affects the mark of one question only. If there is in the examination a large number of relatively simple originals his score is not readily subject to accidental variations. His score will reflect his ability more accurately if the examination is made up of a large number of simple originals. There is less possibility of having momentary confusion affect the total mark. The use of a large number of simple problems eliminates the necessity of giving credit for answers or calculations which are partially correct. It is in the granting of partial credit that the undependable subjective factors enter into the examination mark.

In many subjects it is possible for a clerk to mark the examination papers without knowing anything about the subject. This can be done readily by the objective method because the acceptable answer is specified and it must appear in a specified place on the blank. A clerk can check these answers without understanding the subject. If an examination is given as part of the teaching it is of course advisable for the instructor to follow the mental operations of the student so as to correct his errors. But when an examination is given for the sole purpose of measuring the student's pres-

ent proficiency in the subject the objective procedure can be used with great saving of time for the teaching staff.

III.

Statistical Methods.

Before describing our statistical findings in the present study it may be well to state briefly the nature of the statistical procedures that we have used. These statistical methods can be used to advantage in other similar studies.

Reliability.

The reliability of an examination is not the same as the validity or diagnostic value. By the reliability of the examination we mean the accuracy of the measure itself. An example will make clear the concept of reliability. Suppose that we are measuring distances in a field. If we measure the distances directly with a steel tape we should consider the measurements fairly accurate for ordinary surveying purposes. The measurement would have a certain reliability. If we estimate the distance merely by looking at it the reliability of the measurement would be very low. If we measure the distance by stadia methods the reliability would have a different value and if we make temperature corrections to the steel tape measurement we should have another reliability value for the measurement.

The same concept can be applied to an examination mark. Suppose that a professor used as an examination one of his own pet questions and allows this single question to constitute the whole examination. The reliability of that examination would be very low. If there has been opportunity for coaching among some of the students on the professor's pet questions the reliability of the examination as a measure of student ability is still lower. By this we mean that the examination mark is itself subject to accidental variations which obscure the measurement of student ability. Obviously we should try to reduce to a minimum these extraneous factors that reduce

the reliability of an examination so that differences in examination marks may be interpreted as due solely to differences in ability of students. If we use a large number of simple problems the single errors of the student will not seriously affect the reliability of the examination mark.

Diagnostic Value.

The diagnostic value of an examination is the value of the examination mark as an index of that which the examination purports to measure. If the examination is intended to measure ability in algebra the diagnostic value of the examination would be high if it actually does measure ability in algebra. The diagnostic value of an examination is also spoken of sometimes as the validity of the examination. In order to show clearly the difference between the reliability and the validity of an examination let us consider an extreme example. Suppose that we propose to measure mathematical ability by measuring stature. This would of course be absurd but let us assume that we did not know that it is absurd. If we measure the stature by means of a centimeter scale we should probably determine the stature with considerable accuracy. The reliability of the measure would therefore be high, the measurement as such is accurate. But the validity of the measure for that which we propose to measure, namely, mathematical ability, would be zero because there is no relation between stature and mathematical ability. This will perhaps serve to make clear the fundamental distinction between the reliability of an examination and its validity.

Now let us consider some related inferences that we may make with regard to these two concepts. It is clear that if the reliability of an examination is high it does not at all follow that the validity is acceptable. But if the validity of an examination is known to be high we can assume that the reliability is also high. This should be obvious because if the examination mark agrees closely with the trait that we are attempting to measure we can be fairly sure that the examination mark is itself quite reliable.

If the reliability of an examination is low it can not possibly be a good index of anything. Suppose that we intend to measure stature and that we use such careless or rough measures that the measurement is itself not accurate to within six inches of the right stature. Then we could not possibly expect the unreliable measurement to constitute a good index of stature. The measurement would have low reliability and it would also have low validity as a measure of stature. The same reasoning can be applied to examinations. If the examination is so constructed that its mark has low reliability we can not expect the examination mark to tell us anything about any trait that we may have intended to measure.

If the diagnostic value or validity of an examination is low we can not infer anything regarding the reliability of the examination. It may be either high or low. Suppose that we are measuring ability in mathematics of a group of people who are strangers to us. Suppose that the examination marks that we assign to the individual members of the group agree closely with the judgments of mathematicians who know the group well. Then we should say that the examination has been found to be of high diagnostic value. It has high validity. It agrees well with the trait that we intended to measure. But if the examination marks that we assign should be found to disagree widely from the marks assigned by mathematicians who know the group well, then we should conclude that our examination has low diagnostic value. It does not measure that which we intended to measure. What is the reason? The reason may be of two kinds. The nature of the examination questions may be such that the validity is low. Or the formal aspects of the test may be such that the examination has low reliability. If the test itself is unreliable we can not expect it to agree closely with any trait even though the general nature of the examination questions is correct.

There is a fallacy which occurs frequently among those who are devising educational scales and mental tests. These

writers often pay much more attention to the reliability of their examinations than to the validity. After all, the practical value of the test is in its validity. What does the examination mark tell us about the person who took the examination? That is the important practical question. If that value, the validity, is high, we are satisfied without further inquiry into the reliability of the test mark itself. The main consideration should therefore be given to the practical question of determining what the test actually tells us about the person who takes the examination. The concept of reliability of test score does, however, have some practical importance. If an examination proves to have low diagnostic value it is proper to investigate whether the low validity is due to the unreliability of the examination itself or to the nature of the test questions. To answer that question will point the way to further refinements in the examination by which the practical purpose may be attained. The fallacy of many experimenters in this field is that they pay too much attention to the reliability of the test itself and not enough attention to the fundamental question, the reason for the test, the value of the test in telling us something about the candidate that we did not know before.

Predictive Value.

This concept is closely connected with that of the diagnostic value of a test. If we are using an examination in order to predict future attainment in any specified field we speak of that aspect of the test as its predictive value. It is conceivable that an examination may be serviceable for measuring present attainment and that it will not serve to predict future attainment. In conducting entrance examinations for college students we are interested to discover those students who profit most from the limited facilities of a college. We are then interested in the predictive value of the examinations.

The Correlation Coefficient.

When a physicist desires to state the relation between two variables he plots his concomitant observations on a chart. This reveals whether the function is linear or non-linear, and from such a plot an empirical equation may be derived which shall state in algebraic form the same relation that is depicted by the chart. The scientist who works in the exact sciences is accustomed to find his observations fall along a line. In the social sciences one must be satisfied with relations that are not sufficiently close to yield a graph in which the observations all fall on a line. In many sciences we are unable to control the extraneous variables sufficiently to yield the exact relations with which the physicist is accustomed. If we desire to know the relation between rainfall and accumulated temperature we should first tabulate a large number of paired observations of these two variables. These paired observations would be plotted, and there would be a certain degree of relationship but the observations would by no means fall on one line. There would be considerable scatter on the diagram. Fundamentally the scientific method is the same in the social sciences and the exact sciences.

If some paired observations are plotted on a chart it is possible to determine the constants in an equation which shall fit the observations. This is usually done by the method of least squares. The procedure gives two equations, one for x as the independent variable with y as the dependent variable, and the other equation for y as the independent variable and x as the dependent variable. These two equations are known as the regression equations. The two corresponding lines are known as the regression lines. The correlation coefficient is a function of the slopes of these two lines. It is a pure number which varies between minus one and plus one. When the coefficient is zero it indicates entire absence of relationship between the two variables. When the coefficient of correlation is plus one it indicates that the relation is perfect and direct. When the coefficient is minus one the

relation is perfect but inverse. Intermediate values indicate relative degrees of closeness of association of the two variables.

The Scatter Diagram.

When the paired observations for two concomitant variables are plotted on a chart the result is known as a scatter diagram. Some idea of the relation between the variables can be obtained by inspecting the scatter diagram. If the points on the diagram fall in general in a diagonal direction there is a relation between the two variables. If the slope of the general trend of the points is positive the relation is positive. If the slope is negative the correlation is negative. If the scatter is very considerable the correlation is low, either negative or positive. When the chart is divided into squares according to any convenient units for x and y, and when the number of points in each square is tabulated instead of the individual points, the diagram is known as a correlation table. Whenever we are dealing with data that involve considerable scatter as is usually the case in social and economic data, the first step in the analysis should be to plot a scatter diagram to visualize the nature of the relation. Every scientific problem can be stated in its simplest form by expressing it as a search for the relation between two or more variables.

Percentile Rank.

There is a tendency to increase the use of the percentile rank instead of the absolute examination marks. This practice has fundamental advantages and it is logically sound. Suppose that we assign ordinary examination percentages in examinations in algebra that are given in successive years. We assume that sixty "per cent." is the passing mark. As a matter of fact the passing grade that we designate as a per cent. is not a per cent. at all. There is no guarantee that the difficulty of the examination from one year to the next will remain the same. If one examination is more difficult than the examination for another year and if we maintain the traditional sixty mark as a passing grade we are in reality setting a variable

standard of attainment for successive years. The personal opinion of examiners is no guarantee of constant difficulty of the examination. This has been shown quite conclusively in a recent study conducted under the auspices of the College Entrance Board.

We are justified in assuming that the average efficiency of instruction in algebra throughout the thousands of high schools in the country will remain fairly constant from one year to the next. We shall be reasonably certain that the sixty mark one year means the same as the sixty mark the next year if we adopt the percentile basis of marking papers. The percentile rank is so calculated that it indicates the percentage of the whole group of candidates who score lower than the specified percentage. Thus a percentile rank of 80 means that 80 per cent. of the entire group scores worse and 20 per cent. of the entire group scores better. The average attainment is thus indicated by a percentile of 50. The poorest paper is given a percentile rank of zero and the best examination paper is given a percentile rank of 100. On this basis the percentile rank of any given student indicates directly how he stands in relation to all the others who took the same examination. This can not be known from the ordinary examination mark which is erroneously known as a per cent. mark.

Frequency Distribution.

By frequency distribution we mean the number of persons who attain given examination marks. If we arrange the marks in an examination in groups of ten so that the successive steps on the scale would be 0–10, 10–20, 20–30, etc., and if we list the number of students who attain marks in each of these class intervals we shall have a frequency table. In general we find that the frequencies are low at the extremes of the scale. There are relatively few people who have scores in the tens and twenties and there are relatively few people who get scores in the nineties. The frequencies are much larger in the general middle range of the scale. These frequencies can be plotted and they then become a frequency

curve. The frequency curve usually resembles the probability curve in general outline. The frequency curve is bell shaped, usually high in the middle range and it has low ordinates at the extremes, high and low scores.

IV.

Description of the Tests.

Six tests were used in this investigation. These were called 1 arithmetic, 2 algebra, 3 geometry, 4 intelligence, 5 physics, and 6 technical information.

Test I, Arithmetic Problems.

One might at first sight object to the use of a test in arithmetic with high school graduates who have already demonstrated by high school certification that they are entitled to admission to an engineering course by the customary entrance criteria. This objection would probably be based on the fact that arithmetic as a separate study is not pursued beyond the grammar grades and that the high school student is supposed to have mastered the four fundamental operations. We have included an arithmetic examination in the series, however, with several definite objectives in mind. The test questions have been so selected that they should appeal to the student with engineering interest. The arithmetical calculations called for are of the simplest kind, but the interpretation of the problem which precedes actual calculation requires that the student think in terms which should be interesting to the engineering student. It is not unusual for a student to possess the necessary arithmetical ability for this test who thinks that he can not pass it simply because he is not sufficiently interested in the content to stop and read it carefully. This test is in one of the best tests for the prediction of freshman scholarship in engineering.

The arithmetic examination differs from other examinations for college freshmen mainly in that the problems are relatively simple. It presupposes that the bright and successful student

will solve more of these simple problems in the given time than his less gifted classmates. The differentiation between the students is therefore largely a matter of speed in doing what they all can do.

Test II, Algebra Problems.

This test does not deviate markedly from other algebra examinations. The test contains twelve algebra problems and was given under conditions similar to those of Test I. The time limit for this test is also thirty minutes.

Test III, Geometrical Construction.

The purpose of this test is to determine whether the student is able to apply the principles of plane geometry to simple problems in construction. We have assumed in devising this test that it is possible for a student to memorize the propositions in plane geometry without being able to apply them on the drawing board. The test problems are as follows:

1. Bisect this angle. Show all your construction lines.
2. Draw any triangle with a perimeter equal to the given line. Show all your construction lines.
3. Divide this line into three equal parts. Show all your construction lines.
4. Draw a right-angled triangle with this given line as its hypotenuse. Show all your construction lines.
5. Draw a square so that its area will be equal to the sum of the squares on the given lines. Show all your construction lines.
6. Locate the center of this circle. Show all your construction lines.
7. Draw a line through the given point to the given line so that the angle formed will be equal to the given angle. Show all your construction lines.
8. Extend these two lines and connect them by an arc of ½ inch radius. Show all your construction lines.
9. Draw an arc of ¾ inch radius so that it will be tangent

to the given arc and the given straight line. Show all your construction lines.

The given geometrical data in the form of the necessary lines and arcs were printed in the test pamphlet.

Test IV, Intelligence Examination.

The purpose of an intelligence examination is to ascertain as far as possible the native mentality of the candidate irrespective of his formal education. It is probably not possible to exclude from an intelligence test score the effect of formal education but the intelligence tests in general use certainly minimize this factor as far as possible. The intelligence test used in this study is a combination of six of the best known intelligence tests; namely, analogies, opposites, number completion, sentence completion, the proverbs test and the syllogism test.

Test V, Physics.

This test consists of a series of simple problems in physics. The problems are so stated that the student must select on his own initiative the principles that apply in the solution. The test does not call for any repetition of principles from memory. In fact mere repetition of memorized material is discouraged throughout all these examinations.

Test VI, Technical Information.

In this examination we attempted to ascertain how much general technical information the candidate had acquired during his high school career on his own initiative and by his own interest. For this reason the items are mostly such as would represent activities outside of school. They cover such technical information as a boy would acquire from reading popular technical journals, constructing mechanical toys, inquiring about automobile engines, wireless telegraphy, and the various mechanical and electrical appliances in his immediate environment. If a boy has acquired an extensive fund of such general and semi-popular technical informa-

tion one may be justified in assuming that his interests are fairly stable toward the engineering profession.

The following are some sample items from the test.

Answer these questions by underlining one of the four given answers for each question.

1. A magnet attracts
   brass copper iron platinum
2. An air rifle uses for ammunition
   .22 short BB shot .32 center fire CB caps
3. In making a core for an induction coil one ordinarily uses
   mahogany rubber copper iron
4. Harley-Davidson is the name of a
   motor-cycle electric clock wireless detector aeroplane
5. R. P. M. represents
   volume speed content direction
6. The regulation Ford is equipped on the rear wheels with tires of a diameter of
   $2\frac{1}{2}''$ $3''$ $3\frac{1}{2}''$ $4''$
7. What size wire is most commonly used for wiring a house for 110 volts?
   6 8 14 20
8. The purpose of back gears on a lathe is to
   increase the speed cut threads turn tapers decrease speed
9. Balloons are filled with
   compressed air hydrogen oxygen steam
10. Locks are manufactured by
    Corbin Maydole Starrett Brown and Sharpe
11. If you had to make a strong bolt but could not get steel to make it of, your next choice would be
    cast iron lead wrought iron brass
12. The width of a standard gage railroad track is
    4 feet 4 feet $8\frac{1}{2}$ inches 5 feet 5 feet 6 inches
13. Shellac varnish is thinned by
    distilled water alcohol turpentine gasoline

14. Ordinary concrete contains
asphalt cement glass rubber
15. In sawing off a 10″ board one uses a
cross-cut saw rip saw coping saw turning saw
16. The current used by a two-phase motor is
D.C. static A.C. storage battery
17. Which of these cars have air cooled engines?
Packard Dodge Franklin Ford
18. A frame building is constructed mainly of
brick wood steel tile
19. Lead plate storage batteries are ordinarily filled with a dilute solution of
hydrochloric acid acetic acid sulphuric acid
nitric acid

V.

Norms of Performance.

When the test results were collected for most of the colleges in which the tests had been given the average score for each college freshman class in each of the six tests was calculated. These results are summarized in Table I. In this table will also be found the number of students in each freshman class. From these data one may determine the relative standing of the colleges as regards the general preparation of the freshmen. The rank order of the colleges as determined from these data would not serve in any sense as a guide to the standing of the college as an engineering school because these test results refer only to the examinations of the freshmen entering these institutions. The two California colleges come first in the list as regards the average in the six tests and this might be the basis for some inference with regard to the high schools of that state as compared with the high schools of other states. The state universities admit students on high school certificates and are not in a position to select their students rigidly at the time of admission. For this reason the state universities might ap-

Code Number.	Name of School.	Number of Freshmen Who Took the Tests.						Average Score in Each Test.					
		I.	II.	III.	IV.	V.	VI.	I.	II.	III.	IV.	V.	VI.
1	University of Akron	64	64	62	63	65	63	10.3	3.63	—	82.6	9.8	63
3	University of Alabama	71	71	70	64	64	63	8.4	3	7.5	79.4	9.65	55.7
4	University of Arkansas	47	48	48	50	51	51	9.8	4.2	9.2	83.5	9.0	62.2
6	University of California	83	83	83	83	83	83	13.1	6	9.7	95.0	15.3	71
7	Carnegie Institute of Technology	473	475	465	474	472	470	10.8	4.36	9.6	88.2	10.8	63.3
9	Case School of Applied Science	315	317	317	317	317	316	11.0	4.9	8.5	95.6	11.0	65.5
10	Columbia University	96	97	97	87	88	88	11.7	5.85	10.2	95	12.9	61
11	Cornell University	98	98	98	100	100	99	11.1	5.7	12.1	111.3	12.3	58
12	Drexel Institute	66	66	64	66	63	61	10.1	3.96	7.5	94.5	9.2	65.6
14	Iowa State College, Ames	272	273	—	273	273	277	12.1	5.9	—	91.4	12.5	67.5
15	State University of Iowa	148	147	148	145	146	146	9.4	3.1	8.6	80.4	8.9	63
16	Johns Hopkins University	75	75	74	74	75	75	10.0	4.6	6.4	93	10.1	59.6
17	Kansas State Agricultural College	222	221	217	179	181	178	9.8	3	5.0	83.1	11.8	61.9
18	University of Kansas	234	233	232	230	230	234	10.4	4.3	9.4	80	10.3	60.5
19	Lafayette College	108	108	108	108	109	109	10.3	5.1	7.1	91.5	9.1	57.6
21	University of Maine	220	219	220	220	219	220	8.5	3.8	8.0	86.5	8.35	60
22	Marquette University	107	107	107	106	106	106	9.8	4.05	7.1	87	10.2	61.6
23	Michigan Agricultural College	42	42	42	40	40	40	11.0	4.9	8.1	94	10.0	65.1
24	University of Michigan	537	536	535	514	506	507	10.4	4.1	10.1	89	10.7	64
25	University of Missouri—Mines	94	97	97	97	97	95	10.3	3.6	8.8	86.5	10.0	60.8
26	University of Missouri—Engineering	137	137	137	137	137	137	10.3	4.1	8.94	83	10.0	59.6
28	New Mexico College of Mechanic Arts	26	28	18	27	18	18	9.3	2.75	6.0	79.2	6.4	58.7
29	New York University	61	61	61	56	56	56	10.4	5.46	9.0	79	11.3	56.6
30	University of Nevada	22	22	22	21	21	21	11.5	5.1	8.9	81.5	11.2	68

Code Number.	Name of School.	Number of Freshmen Who Took the Tests.						Average Score in Each Test.					
		I.	II.	III.	IV.	V.	VI.	I.	II.	III.	IV.	V.	VI.
31	Ohio State University	666	667	662	639	639	639	10.6	4.45	8.3	95.5	11.4	62.3
32	Oklahoma Agricultural College	83	83	83	83	83	83	9.4	3.3	9.0	83	10.2	62.2
33	University of Oklahoma	67	67	67	67	67	67	10.5	4.15	6.0	88	10.8	59.5
34	University of Pennsylvania	272	272	267	262	259	256	10.8	4.5	9.4	96.5	10.3	61
35	Purdue University	593	594	589	591	590	584	10.3	2.8	7.8	82	9.8	62.2
36	Rensselær Polytechnic Institute	100	100	100	95	95	95	11.0	4.9	9.7	101	10.4	61.7
37	Rhode Island State College	62	62	51	50	50	62	8.7	4.6	—	87.4	8.1	58.4
38	Rose Polytechnic Institute	92	95	95	89	89	89	10.6	4.5	7.7	91	8.7	62.6
39	Syracuse University	124	124	124	121	121	121	10.9	5.8	8.9	87	11.0	63.6
40	University of Texas	193	188	190	152	135	173	9.6	3.6	—	85.4	8.2	55.3
41	Throop College of Technology (California Institute of Technology)	109	109	107	109	109	109	12.3	5.6	10.8	96.4	15.9	73
42	Tufts College	101	101	101	100	101	100	10.3	4.75	10.8	87.8	10.3	58.7
43	Vanderbilt University	36	36	36	36	36	35	8.8	4.8	—	91	7.7	59.7
44	University of Vermont	55	56	55	56	56	56	9.2	4.5	7.0	90.4	7.9	56
45	University of Virginia	96	96	96	96	96	96	9.5	4.2	9.3	91.6	9.5	60
46	University of Washington, Seattle	368	368	378	402	359	398	10.4	3.7	3.9	85	11.7	65.2
47	Washington University, St. Louis	87	85	87	79	84	85	12.5	5.9	9.1	102	10.5	65.8
48	University of Wisconsin	—	150	—	89	—	27	—	3.44	—	79	—	67
49	Worcester Polytechnic Institute	161	161	161	159	124	159	11.2	5.2	11.4	89.6	11.7	62.9
	Total	6883	7039	6571	6806	6610	6747						
	Average							10.5	4.3	8.4	88.8	10.6	62.5

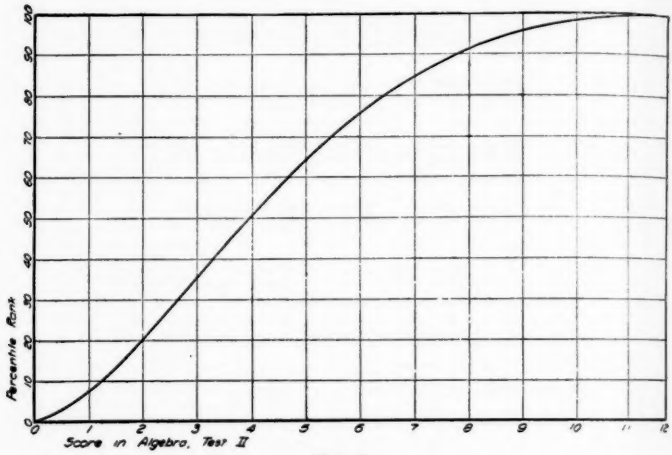

Percentile Rank
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
9
10
11
12
Score in Algebra, Test II

FIG. 3.

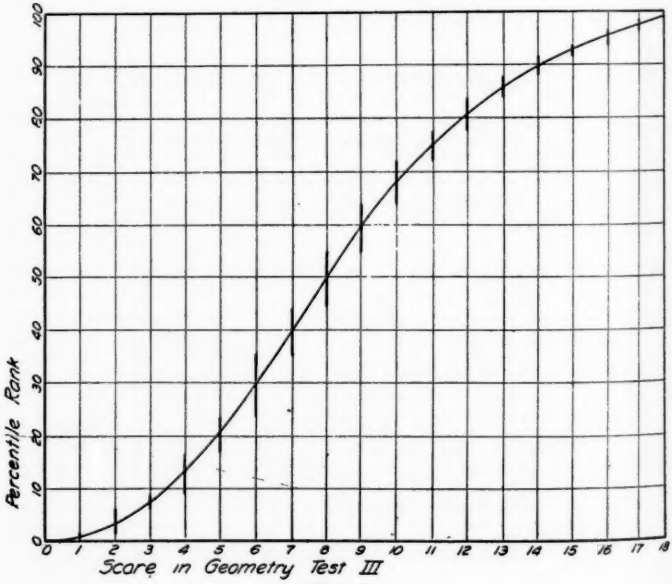

Percentile Rank
0
10
20
30
40
50
60
70
80
90
100
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
Score in Geometry Test III

FIG. 4.

pear at a relative disadvantage in this table. The privately endowed institutions can select their students at the time of admission. The Cornell freshmen score highest in the intelligence test.

With all the data for each test, including a statement of the number of students who attain each score, percentile curves may be drawn as shown in Figs. 2 to 7 inclusive. Consider for example Fig. 2 which is a percentile curve for the arithmetic examination. If a student obtains a score of, let us say, 12 in this examination he has a percentile rank of 64 with reference to the 6,883 engineering freshmen who took this test. The percentile rank of 64 means that 64 per cent. of the six thousand freshmen score lower than he does and that 36 per cent. of them score better. A similar table may be arranged for a smaller group such as the freshmen class of a single college. By using such a table or chart one can readily state the relative position of any student in any examination with reference to his classmates. The percentile rank tells more about the student than the customary school percentage mark with its passing level of 60 "per cent." The sixty per cent. passing mark of the school grades is an entirely arbitrary mark which depends on such uncontrollable factors as the relative difficulty of the examination, the number of questions in it, the time devoted to it, the manner of marking it, the personal opinions of the examiner who marks the paper, and the time when he happens to be marking it.

In Fig. 5 we have the percentile curves for 6806 engineering freshmen in an intelligence test, 5495 liberal arts freshmen and 1575 normal school students. Inspection of these three percentile curves based on the same intelligence test administered under similar conditions, shows that the engineering freshmen score on the average higher in intelligence than liberal arts freshmen although the difference is not great, and that the engineering freshmen score considerably higher than normal school students. This is probably caused by the fact that the entrance requirements for an engineer-

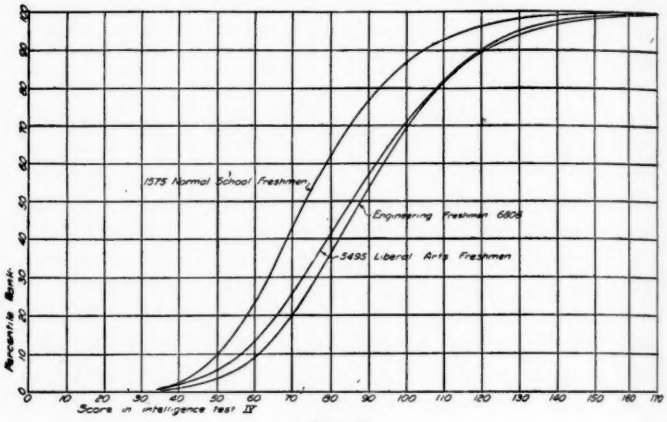

1575 Normal School Freshmen
Engineering Freshmen 6808
5495 Liberal Arts Freshmen
Percentile Rank
Score in Intelligence Test II

FIG. 5.

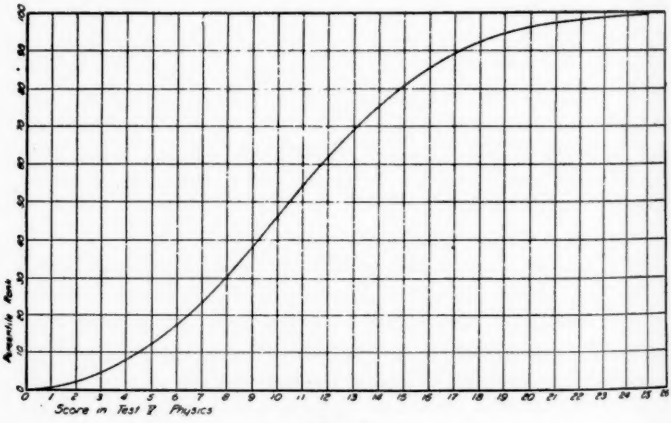

Percentile Rank
Score in Test V Physics

FIG. 6.

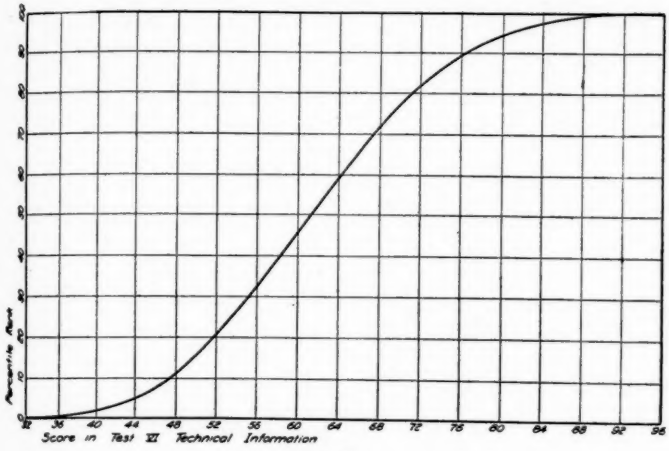


FIG. 7.

ing course and the reputation that such courses have for relative difficulty tend to select for admission the relatively superior high school graduates. These findings are in accord with the corresponding findings in the army where the engineers scored in general higher in the army intelligence examination than officers representing the other professions.

Inter-test Correlations.

When several tests are used in a combined program it is desirable that the tests measure, as far as possible, different mental abilities so that the combined use of the several tests covers as wide a range of mentality as possible. For this reason it is desirable that the inter-test correlations should be low. If the inter-test correlations are high the several tests are probably measuring the same mental trait. It is of some statistical interest to know the inter-relations of the six tests. These have been tabulated in Table II for four of the larger colleges together with the average inter-test correlation for each pair of tests.

TABLE OF INTER-TEST CORRELATIONS—TESTS I–VI. S. P. E. E.

		Arith.	Algebra.	Geometry.	Intell.	Physics.	Tech. Inf.
		I.	II.	III.	IV.	V.	VI.
I. Arith.	Univ. of Mich.		.53	.25	.58	.58	.28
	Carnegie Inst. Tech.		.50	.39	.54	.55	.37
	Purdue University		.54	.45	.55	.58	.46
	Ohio State Univ.		.56	.40	.53	.53	.26
	Average		.53	.37	.55	.56	.34
II. Alg.	Univ. of Mich.	.53		.44	.27	.40	.01
	Carnegie Inst. Tech.	.50		.35	.14	.35	.14
	Purdue University	.54		.38	.38	.38	.24
	Ohio State Univ.	.56		.35	.44	.39	.15
	Average	.53		.38	.31	.38	.14
III. Geom.	Univ. of Mich.	.25	.44		.13	.30	.25
	Carnegie Inst. Tech.	.39	.35		.23	.42	.24
	Purdue University	.45	.38		.22	.43	.45
	Ohio State Univ.	.40	.35		.26	.43	.33
	Average	.37	.38		.21	.40	.32
IV. Intell.	Univ. of Mich.	.58	.27	.13		.36	.24
	Carnegie Inst. Tech.	.54	.14	.23		.38	.16
	Purdue University	.55	.38	.22		.28	.34
	Ohio State Univ.	.53	.44	.26		.35	.23
	Average	.55	.31	.21		.34	.24
V. Phys.	Univ. of Mich.	.58	.40	.30	.35		.44
	Carnegie Inst. Tech.	.55	.35	.42	.38		.50
	Purdue University	.58	.38	.43	.28		.51
	Ohio State Univ.	.53	.39	.43	.35		.41
	Average	.56	.38	.40	.34		.46
VI. Tech. Inf.	Univ. of Mich.	.28	.01	.25	.24	.44	
	Carnegie Inst. Tech.	.37	.14	.24	.16	.50	
	Purdue University	.46	.24	.45	.34	.51	
	Ohio State Univ.	.26	.15	.33	.23	.41	
	Average	.34	.14	.32	.24	.46	
	Average	.47	.35	.33	.33	.43	.30

VI.

FIRST YEAR SCHOLARSHIP AS A CRITERION.

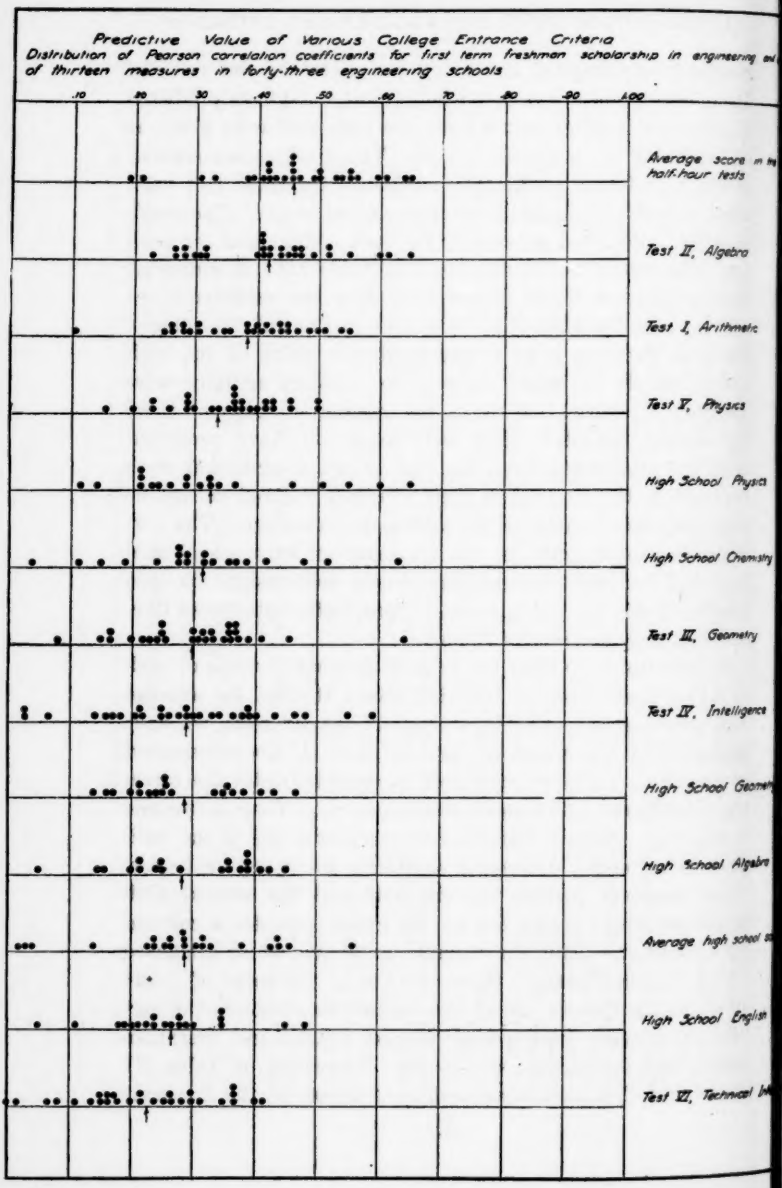
When the students in the various colleges that gave the six tests had completed one year of academic work the scholarship

Name of School.	Pearson Correlation Coefficient for Each Test and Average First Term Freshman Scholarship.							Pearson Correlation Coefficient for Each High School Subject and Average First Term Freshman Scholarship.						No. Cases Aver. H. S. Scholarship.	Selection Ratio.
	I.	II.	III.	IV.	V.	VI.	Aver. I–VI.	Eng.	Geom.	Alg.	Phys.	Chem.	H. S. Aver.		
Univ. of Akron	.328	.31	.153	.29	.37	.37	.216	.05	.14	.16	−.23	.12	.04	25	
Univ. of Alabama	.11	.30	.08	.43	.36	−.02	.185	.11	.22	.39	.55	.42	.27	46	.99
Univ. of Arkansas	—	—	—	—	—	—	—	—	—	—	—	—	—		
Univ. of California	—	—	—	—	—	—	—	—	—	—	—	—	—		
Carnegie Institute of Technology	.50	.41	.37	.33	.40	.30	.55	.24	.23	.39	.24	.29	.29	421	.37
Case School of Applied Science	.38	.407	.33	.25	.30	.11	.65	.35	.37	.39	.34	.44	.37	253	.80
Columbia University	.42	.455	.355	.376	.46	−.08	.49	—	—	—	—	—	—		
Cornell University	.44	.319	.41	.307	.504	.37	.565	—	—	—	—	—	—		
Drexel Institute	.27	.27	.64	.21	.34	.267	.595	.24	.17	.15	.51	.28	.29	61	
Iowa State University, Ames	—	—	—	—	—	—	—	—	—	—	—	—	—		
State University of Iowa															1.00
Johns Hopkins University	—	—	—	—	—	—	—	—	—	—	—	—	—		
Kansas State Agricultural College	.445	.49	.22	.386	.457	.368	.606	.35	.35	.36	.22	.58	.33	198	1.00
University of Kansas	.47	.62	.175	.388	.23	.14	.41	.35	.27	.41	.26	.15	.26	188	1.00
Lafayette College	.356	.604	.32	.47	.415	.35	.641	.48	.41	.35	.46	.48	.46	110	.83
Univ. of Maine	.28	.28	.39	.21	.42	.41	.445	.45	.47	.36	.33	.32	.43	111	.91
Marquette University	.397	.518	.32	.29	.37	.165	.47	.23	.26	.22	.12	.04	.24	97	.63
Michigan Agricultural College	—	—	—	—	—	—	—	—	—	—	—	—	—		
University of Michigan	.41	.47	.255	.254	.29	.16	.42	.28	.36	.38	.29	.32	.38	243	.89
University of Missouri—Mines	—	—	—	—	—	—	—	—	—	—	—	—	—		
University of Missouri—Engin.	.454	.42	.368	.16	.376	.20	.46	—	—	—	—	—	—		
New Mexico College of Mech. Arts	—	—	—	—	—	—	—	—	—	—	—	—	—		

Name of School.	Pearson Correlation Coefficient for Each Test and Average First Term Freshman Scholarship.							Pearson Correlation Coefficient for Each High School Subject and Average First Term Freshman Scholarship.						No. Cases Aver. H. S. Scholarship.	Selection Ratio.
	I.	II.	III.	IV.	V.	VI.	Aver. I–VI.	Engl.	Geom.	Alg.	Phys.	Chem.	H. S. Aver.		
New York University	.477	.407	.35	.55	.498	−.177	.496	.28	.38	.42	.65	.52	.56	58	.80
University of Nevada	.44	.44	.33	.37	.37	.27	.53	.27	.24	.24	.29	.36	.32	390	.93
Ohio State University	.253	.524	.36	.258	.43	.40	.464	—	—	—	—	—	.29	24	1.00
Oklahoma Agricultural College	—	—	—	—	—	—	—	—	—	—	—	—	—	—	
University of Oklahoma	.28	.315	.202	.146	.29	.225	.335	.18	.20	.05	.21	.24	.23	154	.72
University of Pennsylvania	.51	.46	.374	.343	.39	.293	.53	.22	.26	.28	.21	.29	.27	596	.75
Purdue University	.275	.27	.17	−.03	.165	.15	.46	—	—	—	—	—	.019	92	.83
Rensselaer Polytechnic Institute	.308	.409	.237	.17	−.019	.306	.42	—	—	—	—	—	—	86	.89
Rhode Island State College	.29	.46	.25	−.028	.23	.22	.38	.29	.25	.45	.31	.63	.44	86	.80
Rose Polytechnic Institute	.384	.40	.248	.067	.196	.241	.42	.21	.17	.25	.37	.28	.32	120	.89
Syracuse Univ.	.349	.448	.23	.40	.33	.17	.31	—	—	—	—	—	—		
Univ. of Texas	.43	.416	.36	.30	.26	.16	.43	—	—	—	—	—	—		.87
Throop College of Technology	—	—	—	—	—	—	—	—	—	—	—	—	—		
Tufts College	—	—	—	—	—	—	—	—	—	—	—	—	—		
Vanderbilt University	.55	.65	.30	.485	.43	0	.50	.30	.43	.20	.60	.19	.14	55	.72
University of Vermont	.535	.55	.46	.214	.359	.07	.556	.19	.34	.21	.14	.28	.03	83	
University of Virginia	.387	.435	.308	.28	.377	.262	.465	—	—	—	—	—	.24	394	.95
University of Washington, Seattle	—	—	—	—	—	—	—	—	—	—	—	—	—		
Washington University, St. Louis	—	.227	—	.59	—	—	—	—	—	—	—	—	—		.97
University of Wisconsin	.31	.286	.30	.18	.29	.30	.39	.26	.21	.25	.33	.33	.31	160	.54
Worcester Polytechnic Institute															
Total															
Average	.38	.42	.30	.29	.34	.23	.46	.27	.29	.29	.33	.32	.29		

records were compiled and checked against the test records. The question now arises as to whether one could have predicted the scholarship attainments from the tests that were given at the beginning of the freshman year. This question is answered by the correlation coefficients calculated for these two variables; namely, scholarship records and test scores. The coefficient was calculated separately for each college and for each test. The results are summarized in Table III. A glance at these coefficients shows immediately that the coefficients are not very high for some of the tests and for some of the colleges. The next question is as to the predictive value of the high school records by which these same students actually were admitted to college. What is the predictive value of these high school records? How well could one have predicted scholastic attainment from the high school records that were available at the time when these students entered college or when they were applying for admission to college. The corresponding coefficients for the fundamental high school subjects and for the average high school scholarship are also listed in Table III. A glance at these coefficients shows likewise that they are relatively low.

In order to make clear the relative diagnostic value of each of the six tests, each of the high school studies, the average high school grade, and the average in the six tests, we have prepared Fig. 8 in which the data of Table III are represented graphically. The scale from left to right indicates the correlation coefficient which theoretically can vary from minus one to plus one. Each horizontal line represents one of the variables which might determine eligibility for college entrance. These variables include the six tests and the several high school subjects. Every dot on the chart indicates a correlation coefficient. Thus, for example, in the line which is marked "High School Physics" there is a dot at the value of + .24 which means that at one of the engineering colleges the correlation between high school physics marks and freshman engineering scholarship was + .24. Inspection of Table III shows that this particular coefficient refers to the Carnegie


Predictive Value of Various College Entrance Criteria
Distribution of Pearson correlation coefficients for first term freshman scholarship in engineering
of thirteen measures in forty-three engineering schools
.10
.20
.30
.40
.50
.60
.70
.80
.90
1.00
Average score in
half-hour tests
Test II, Algebra
Test I, Arithmetic
Test V, Physics
High School Physics
High School Chemistry
Test III, Geometry
Test IV, Intelligence
High School Geometry
High School Algebra
Average high school
High School English
Test VI, Technical

Institute of Technology. Where several colleges are listed with identical coefficients for the same test or school subject the dots are arranged vertically over each other. The small vertical arrowhead on each of the horizontal lines indicates the average correlation coefficient for all the colleges for which data are available. Thus the average diagnostic value of high school physics for predicting freshman scholarship is .33 for all the colleges represented in the data.

It will be seen that the entrance variables are arranged in descending order from the highest average correlation coefficient to the lowest. Thus the best prediction is obtained by the pooled score in all the six tests, and the poorest diagnostic value is that of the technical information test when taken alone. The various individual tests and high school subjects take intermediate ranks in diagnostic value.

If we inspect Fig. 8 we find the following facts with reference to the value of various facts for determining admission. An examination in algebra for thirty minutes gives on the average higher predictive value with reference to freshman engineering scholarship (.42) than the high school grade in algebra (.29). This represents the average for all the colleges in which the records were compiled. An examination in physics for thirty minutes gives practically the same predictive value (.34) as the high school mark in this subject (.33). The half-hour test in constructive geometry gives practically the same predictive value (.30) as the high school grade in the same subject (.29). The entrance examinations in algebra, arithmetic, physics, chemistry, and geometry give higher predictive value with reference to freshman engineering scholarship than the intelligence test. This is to be expected because of the heavy loading of mathematics and physics in the freshman engineering curriculum. The half hour intelligence test gives higher predictive value for engineering freshman scholarship (.29) than the high school grade in English (.27) although this difference is hardly sufficient to be considered stable and significant. The two criteria are practically comparable in diagnostic value. The average marks in a three-

INTELLIGENCE TESTS FOR ENGINEERING STUDENTS.

SHOWING THE DIAGNOSTIC VALUE OF THE TESTS BASED ON DATA FROM THE CARNEGIE INSTITUTE OF TECHNOLOGY.

	No. of Students in Each Quarter of the Class.	No. Dropped for Poor Scholarship.	No. Transferred to Other Departments.	No. Withdrawn for Other Reasons.	Total Withdrawn.	Probability of Remaining in Good Standing at End of Three Months.
Arithmetic:						
Highest Quarter	118	4	3	3	10	.91
Second Quarter	118	5	0	8	13	.89
Third Quarter	118	10	1	8	19	.84
Lowest Quarter	118	25	12	18	55	.53
Algebra:						
Highest Quarter	118	4	4	8	16	.87
Second Quarter	118	3	1	4	8	.93
Third Quarter	118	24	1	6	31	.74
Lowest Quarter	118	13	10	18	41	.65
Geometry:						
Highest Quarter	116	2	0	4	6	.95
Second Quarter	116	4	4	4	12	.90
Third Quarter	116	13	5	11	29	.75
Lowest Quarter	116	23	7	12	42	.64
Physics:						
Highest Quarter	118	5	0	6	11	.91
Second Quarter	118	10	0	6	16	.87
Third Quarter	118	8	5	10	23	.81
Lowest Quarter	118	21	10	14	45	.62
Technical Information:						
Highest Quarter	118	5	0	8	13	.89
Second Quarter	118	11	2	2	15	.87
Third Quarter	118	10	4	7	21	.82
Lowest Quarter	118	17	9	19	46	.62
Psychological Examination:						
Highest Quarter	118	5	3	5	13	.89
Second Quarter	118	5	0	7	12	.90
Third Quarter	118	15	6	12	33	.72
Lowest Quarter	118	9	7	13	39	.66
Rank According to Mid Percentile of All Tests						
Highest Quarter	116	2	1	5	8	.93
Second Quarter	116	5	0	7	12	.89
Third Quarter	116	13	3	5	21	.81
Lowest Quarter	116	24	11	19	54	.53

hour examination program including all six of the tests gives a much higher predictive value for engineering freshman scholarship (.46) than the average mark in the four-year high school course (.29).

It may seem strange that a three hour examination should give more reliable prediction of the student's capacity for college work than his average attainment in four years of high school work. This finding is probably due to the fact that the high school grades vary considerably, the same mark meaning different standards in different schools. The examinations were conducted as uniformly as possible in all the participating colleges and the papers were marked in a predetermined way.

TABLE OF CORRELATION COEFFICIENTS.

Total quality points in two years, 1919–1920 and 1920–1921, and

High School Grades.	r.
Algebra	.21
Geometry	.22
English	.21
Physics	.25
Chemistry	.29
Average	.28
S. P. E. E. Test Scores.	
Test I Arithmetic	.45
Test II Algebra	.30
Test III Geometry	.35
Test IV Intelligence	.29
Test V Physics	.36
Test VI Technical Information	.22
Average	.48

Quality points for 1919–20 and total quality points = .89.
Quality points for 1919–20 and quality points 1920–21 = .75.

The first line of the table is read as follows: Of the 118 students obtaining the highest quarter of the scores in Arithmetic, 4 were dropped for poor scholarship, 3 others were transferred, 3 others were withdrawn for other reasons, making a total of 10 withdrawn. Since there were 108 left in good standing at the end of three months, the probability that a student making a score in the highest quarter will remain in good standing at the end of three months is .91, the ratio of 108 to 118. The other lines of the table are read in a similar manner.

In Table IV we have listed an analysis of the several tests and their correspondence with the scholastic record of the freshman entering Carnegie Institute of Technology in the fall of 1919. Thus, for example, if we divide the total freshman class into four equal parts based on their scores in the arithmetic test we have 118 students in each quarter. Among the students in the highest quarter of the class, divided according to the arithmetic test, we have four that were dropped for poor scholarship during the first semester. In the lowest quarter of the class there were twenty-five students dropped for poor scholarship. The other columns are interpreted in the same way.

VII.

Two Year Scholarship as Criterion.

The records of these examinations have been on file for two years, and it is time to compare the marks made in these examinations with the attainments of the students who entered these colleges in 1919. This chapter concerns such an analysis for the 490 freshmen who entered the engineering college at Carnegie Institute of Technology in 1919. These students were given the six examinations just mentioned and their scores in each test were tabulated. We also tabulated their high school grades in each of the following subjects: algebra, plane geometry, English, physics and chemistry. Besides these individual grades and examination marks, we listed the average high school scholarship and the average grade in the six special examinations.

This gives me thirteen independent variables for the study. The dependent variable is throughout the average college scholarship for the first two years of the engineering course. The practical question is how to determine which of these various high school grades and examinations could serve best to predict what a student will do in his college course.

In Table V, we have listed the correlation coefficient for two years' college scholarship as a criterion and each of the thirteen independent variables. The diagnostic value of a

test or grade with reference to freshman and sophomore scholarship in college can be inferred from these coefficients.

It will be found that the coefficients in Table V range from .21 to .48. The highest diagnostic value with reference to two years of college scholarship is obtained from the average mark in the three hour examination prepared by the committee. The grade in high school English is found to have the lowest predictive value. It is reasonable to expect that the grade in English should not correlate closely with attainment during the first two years of an engineering course because the instruction during these two years is heavily loaded with mathematics, physics, chemistry, mechanics, and drafting. It is conceivable that a student may be poor in high school English either from lack of ability or from lack of interest and still show high attainment in a scientific curriculum. The reason for such discrepancy is perhaps most frequently lack of interest.

The table of correlation coefficients also shows that a thirty minute arithmetic examination has almost as high a diagnostic value as the full three hour program. This is to be considered quite remarkable in view of the fact that the arithmetic examination required only thirty minutes of the applicant's time.

It is interesting to note the predictive value of a half hour test in physics and the high school grade in physics. On the basis of my findings in this table the half hour physics examination has higher diagnostic value than the high school physics grade when the criterion is the first two years' scholarship.

The same table affords a comparison between the relative predictive value of the high school grade in plane geometry and a half hour examination in constructive geometry. The correlation coefficients show the higher diagnostic value of the examination.

A similar comparison was made between the high school grade in algebra and a thirty minute examination in algebra.

This comparison also is in favor of the examination proceddure as judged by the correlation coefficients.

Turning now to the examinations and high school courses which do not bear directly on the engineering curriculum of the freshman and sophomore years, we find, for example, that a half hour intelligence examination gives a predictive value as high as or higher than the average four year high school scholarship.

The reader should note in Table V that five of the six examinations rank higher in diagnostic value than the high school grades. All but one of the special examinations give correlations of .29 or higher whereas all of the high school grades give correlations of .29 or lower. The exception to this finding is with the general technical information test. This test was intended to measure more or less roughly the range of the student's information about mechanical and electrical facts in his immediate environment. The examination does not have reference to any high school course of instruction. It is intended to indicate to what extent the student has by his own interest and initiative obtained technical information. The fact that this examination does not correlate higher than the high school grades shows that it is not more reliable than high school scholarship. This fact would seem to indicate that if a boy has acquired extensive information about mechanical and electrical things we can not, therefore, conclude that he will be a successful engineering student in the first two years of his course. It is probably caused by the fact that ability to survive through the first two years of the engineering curriculum is analytical rather than practical and concrete. It would be interesting to note whether this Test VI changes its place relative to the other examinations when we obtain records of these same students in their more strictly professional courses of the junior and senior years.

Figure 9 represents graphically the diagnostic value of average high school scholarship and the average standing in the six S. P. E. E. examinations. One of these graphs repre-

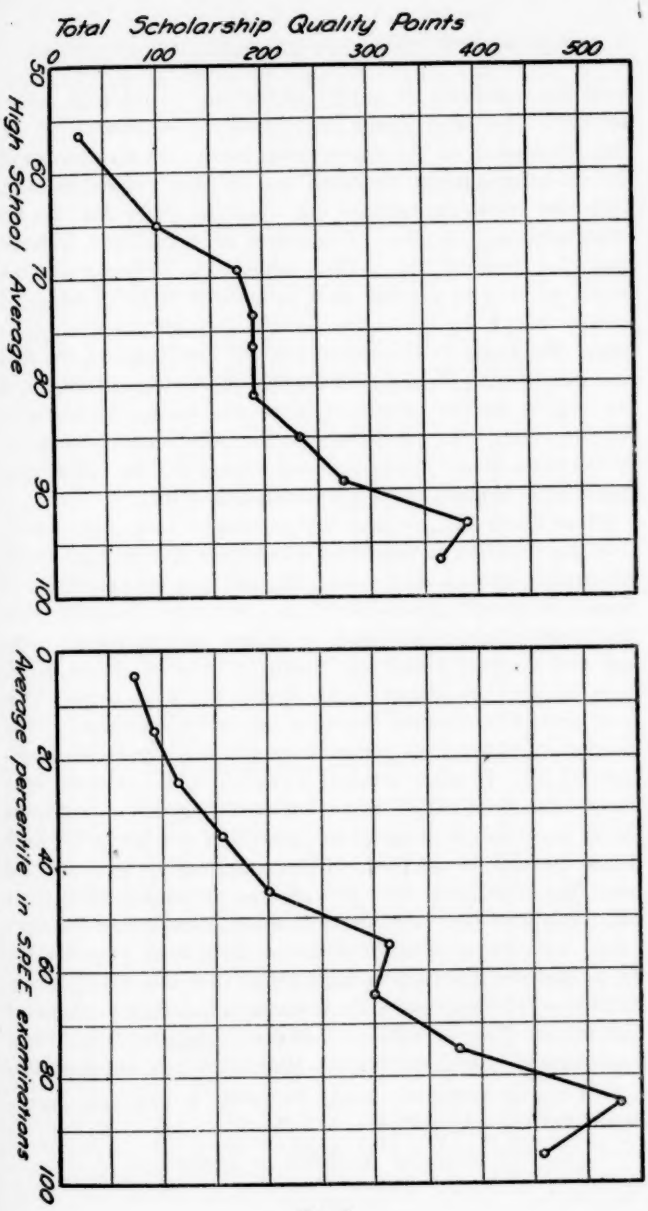

Total Scholarship Quality Points
0
100
200
300
400
500
50
60
70
80
90
100
High School Average
0
20
40
60
80
100
Average percentile in S.R.E.E. examinations

FIG. 9.

sents the regression of college scholarship on the high school average. The other graph represents the regression of college scholarship on the examination score. As an average of the six examinations we listed the average percentile rank. This was advisable because the absolute scales for the six tests vary considerably. The slopes of these lines indicate that if a student has a high scholarship average in high school, he will in general tend to make a higher average in college than if he has a low average in high school scholarship. Referring to the second part of the diagram, we find also that the higher a student scores in the six examinations the higher on the average will be the college scholarship. Note especially that the differentiation in scholarship obtained by the three hour examination is greater than the differentiation that is obtained by high school scholarship.

From Table III, we find that the three hour examination gives a correlation coefficient of .48 whereas average high school scholarship gives a corresponding coefficient of .28. Both of these refer to college scholarship as a criterion. Now the practical question arises as to whether we can combine the examination and the high school scholarship in order to obtain a still more reliable prediction of the student's college work. This is a partial correlation problem in three variables.* The diagnostic value of the combination gives a correlation coefficient of .53. In other words if we should admit students by a three hour examination alone, we should expect a diagnostic value of .48 and if we go to the trouble of averaging the high school records in addition to the examination we raise the reliability from .48 to .53. It is an open question as to whether the labor involved would justify us in considering the high school scholarship in addition to the three hour examination. In addition to this fact we must recall that this study is confined to a freshman class, all of whom had actually completed high school. The correlation of .48 would probably be increased considerably if applicants were allowed to take the examina-

*"A Scoring Method for Mental Tests," L. L. Thurstone, *Psychological Bulletin*, July, 1919, Vol. XVI, No. 7.

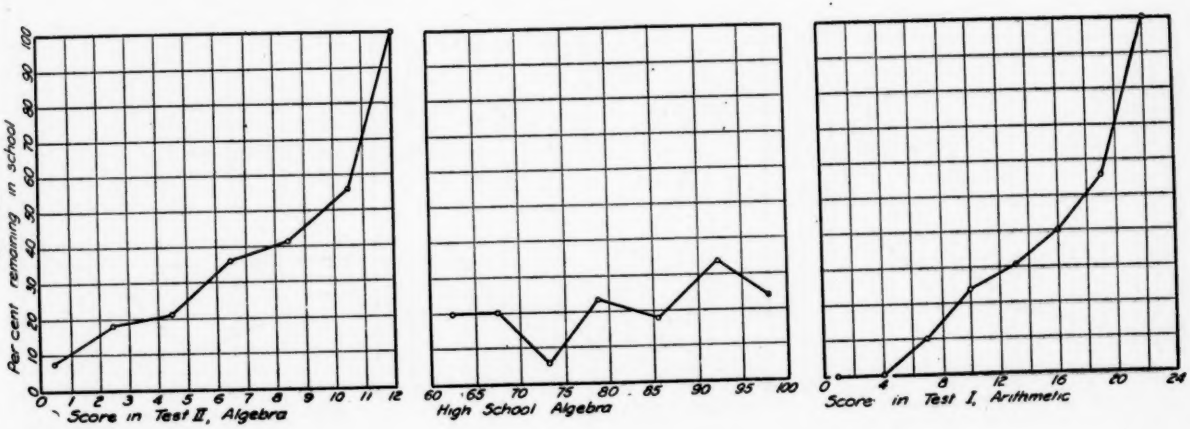

Per cent remaining in school
0 10 20 30 40 50 60 70 80 90 100
0 1 2 3 4 5 6 7 8 9 10 11 12
Score in Test II, Algebra
60 65 70 75 80 85 90 95 100
High School Algebra
0 4 8 12 16 20 24
Score in Test I, Arithmetic

Fig. 10.

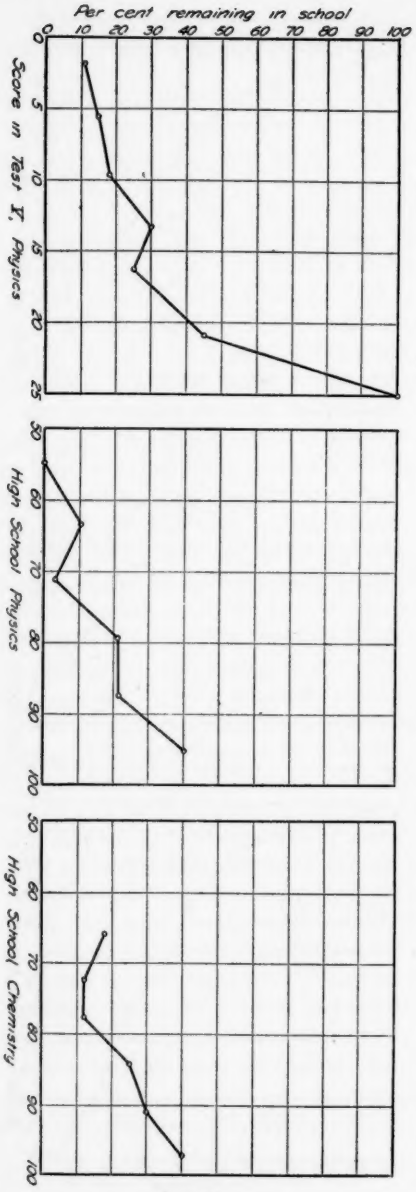

Per cent remaining in school
0 10 20 30 40 50 60 70 80 90 100
Score in Test I, Physics
0 5 10 15 20 25
High School Physics
50 60 70 80 90 100
High School Chemistry
50 60 70 80 90 100

FIG. 11.

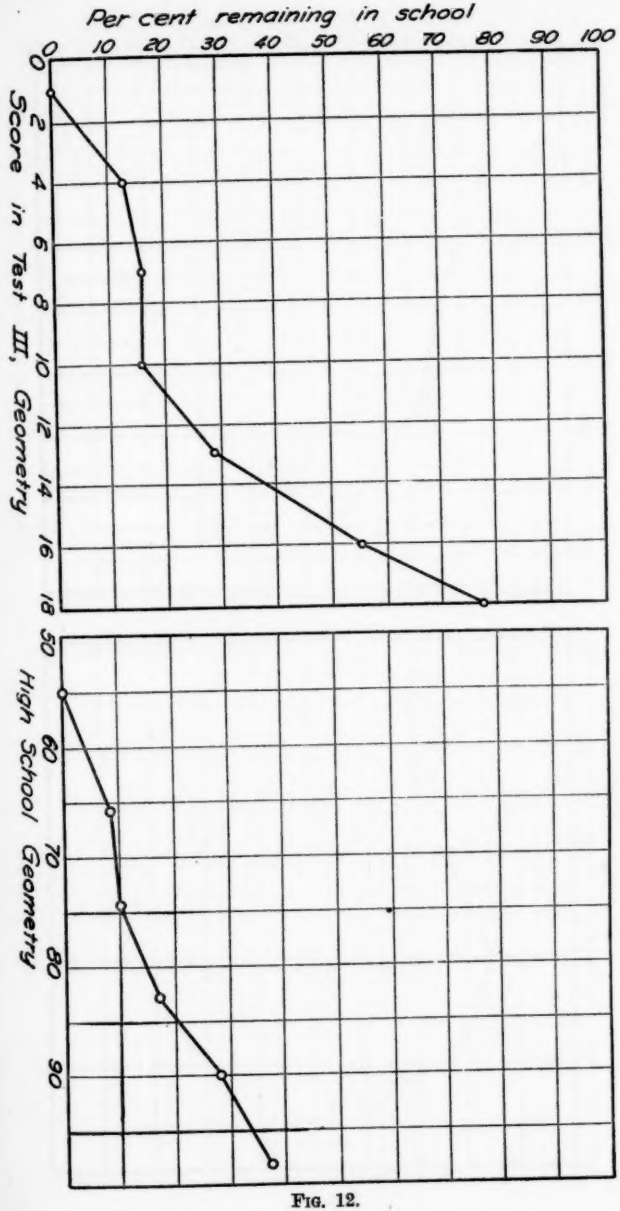

Per cent remaining in school
0 10 20 30 40 50 60 70 80 90 100
Score in Test III, Geometry
0 2 4 6 8 10 12 14 16 18
High School Geometry
50 60 70 80 90

FIG. 12.

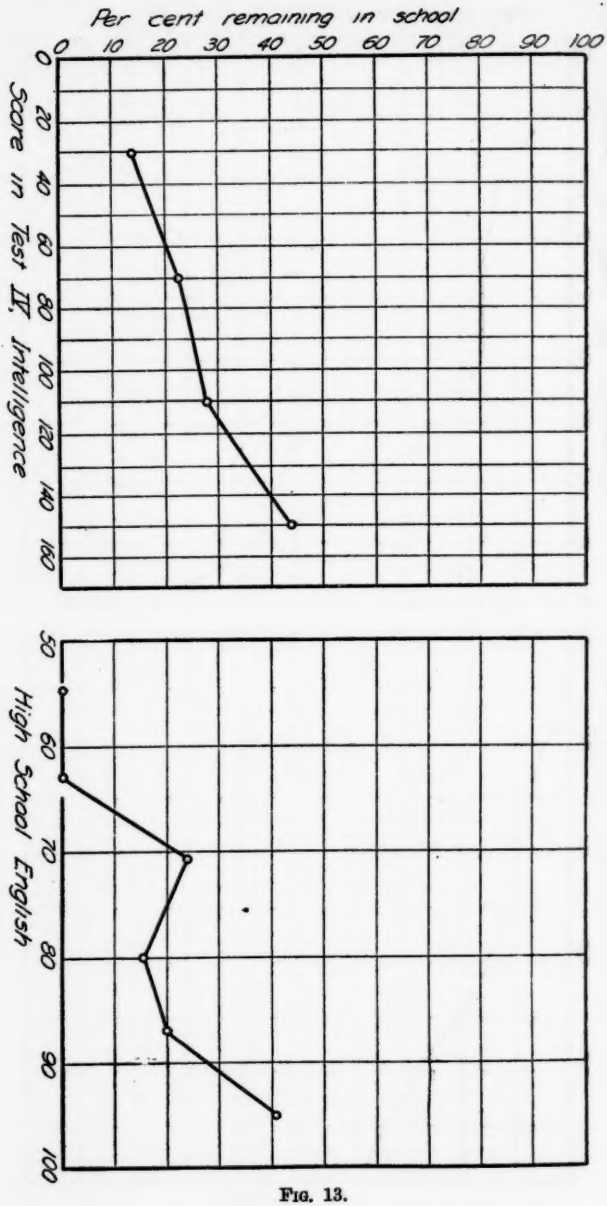

Per cent remaining in school
0 10 20 30 40 50 60 70 80 90 100
Score in Test II, Intelligence
0 20 40 60 80 100 120 140 160
High School English
50 60 70 80 90 100

FIG. 13.

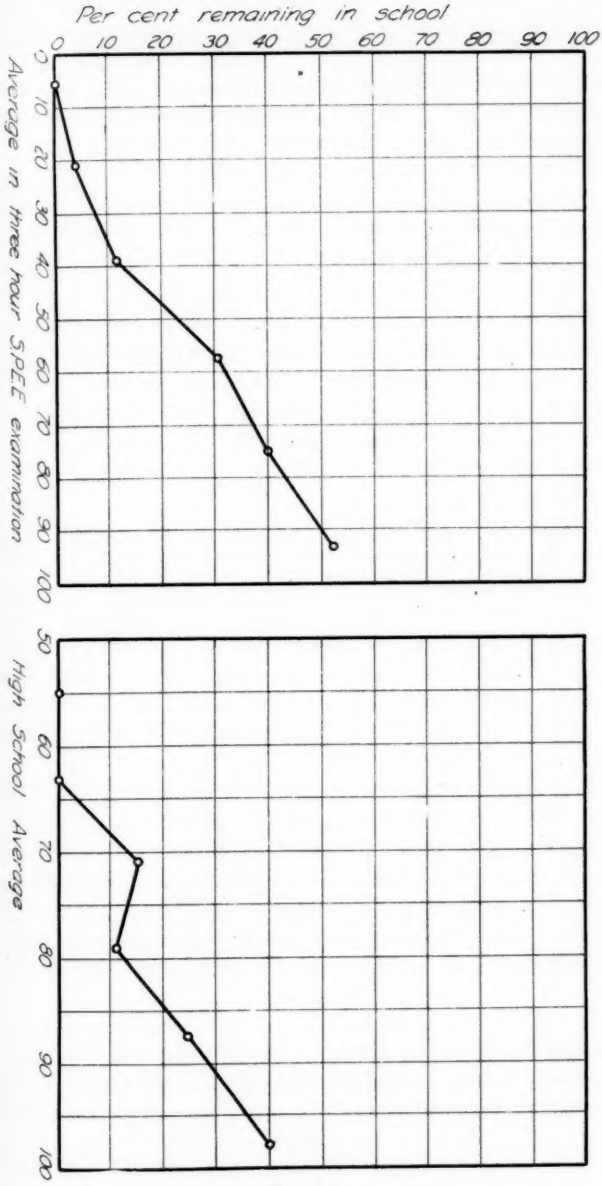

Per cent remaining in school
0 10 20 30 40 50 60 70 80 90 100
Average in three hour S.P.E.E. examination
0 10 20 30 40 50 60 70 80 90 100
50 60 70 80 90 100
High School Average

FIG. 14.

tion irrespective of high school graduation. This would increase the range of the independent variable and that almost invariably results in a higher correlation coefficient.

Let us compare the relative diagnostic value of the one half hour algebra examination, the one half hour arithmetic examination, and the high school algebra grades. These comparisons can be made in Fig. 10. In the first part of this figure we have the percentage of students remaining in college plotted against score in the thirty minute algebra test which was given two years ago. Among those who made scores between zero and two in this test, only 10 per cent. remained in college for two years. All of those who made scores of twelve in this test remained in college. It should be apparent that the steeper the slope of this graph the higher will be the differentiating value.

In the second part of Fig. 10, we have made a similar tabulation for the high school grade in algebra. A slight positive slope can be imagined for this irregular diagram. It can readily be seen from the chart that practically the same percentage of students making high grades in high school algebra remained in college as among those who made low grades in high school algebra. It therefore is evident that a half-hour examination in algebra has considerably higher predictive value than the high school grade in the same subject.

The corresponding results for Test I, Arithmetic, in the third part of Fig. 10 are represented graphically. Note that either one of these examinations requiring only thirty minutes each is more reliable for predicting the student's success in college than the high school algebra grade in spite of the fact that the high school grade represents, supposedly, a judgment based on one year's acquaintance with the student.

In Fig. 11, a similar analysis of the thirty minute examination in physics and the high school grades in physics and in chemistry is made. The angles on this chart will show that the one half hour examination is in this subject also more

diagnostic of success in college than the high school grades in the same or comparable subjects.

Fig. 12 represents the same type of comparison for geometry. Here as before the thirty minute geometry examination is found to be more diagnostic than the high school grade in the same subject. The criterion is in all of these cases the probability of completing two years of college work.

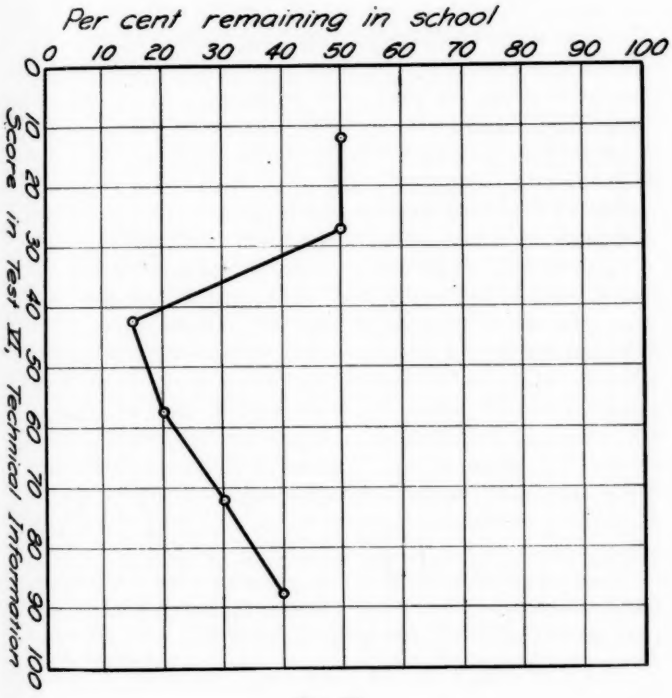

Per cent remaining in school
0 10 20 30 40 50 60 70 80 90 100
Score in Test II, Technical Information
0 10 20 30 40 50 60 70 80 90 100

FIG. 15.

Fig. 13 represents the same analysis for the intelligence test and for high school English. Neither of these examinations is as reliable in predicting success in the engineering

course as the subject matter examinations with special reference to the engineering curriculum. It is, however, interesting to note that the thirty minute intelligence test does not compare unfavorably with the diagnostic value of the average high school grade in three years of English.

In Fig. 14, corresponding graphs are plotted for the average in the three hour S. P. E. E. examination and for average high school scholarship. The three hour examination has more differentiating value than the average high school scholarship.

In Fig. 15, a similar graph has been plotted for Test VI, Technical Information. This test has no diagnostic value as may be seen from the chart. A similar analysis for this test for first year students showed some diagnostic value but this seems to have disappeared in changing the criterion to two years' retention in college. The graph might be explained as indicating that those students who knew very little about practical mechanical and electrical appliances are more interested in the theoretical subjects of their high school course and therefore succeed better in the engineering school than those students who devote their major time and interest to mechanical and electrical toys and to the study of periodicals with such content. It seems as though two factors are here at work. Other things being equal, that engineering student will succeed who has an abiding interest in engineering things even before entering his college course. On the other hand, other things being equal, that student will devote much time and interest to concrete mechanical and electrical toys during his high school years who is not mentally able to succeed in the more abstract subjects of the high school curriculum. These two factors work in opposite directions and their combination may perhaps be responsible for the peculiar graph of Fig. 15.